1001 Inventions

Muslim Heritage in Our World

Second Edition

Chief Editor
Salim T S Al-Hassani

Co-editors
Elizabeth Woodcock & Rabah Saoud

Foundation for Science Technology and Civilisation

CONTRIBUTORS TO THIS BOOK

Much of the material for this book is based on articles published on www.MuslimHeritage.com. Principal articles are written by the following scholars, arranged in alphabetical order:

Professor Mohammed Abattouy (Engineering and Mechanics)
HRH Princess Wijdan Ali (Art and Islamic coins)
Dr Salim Aydüz (Ottoman Science)
Dr. Subhi Al-Azzawi (Architecture)
Professor Charles Burnett (Medicine and Mathematics)
Dr Mahbub Gani (Mathematics and numbers)
Professor S M Ghazanfar (Muslim Spain)
Professor Salim T S Al-Hassani (Engineering)
Dr Zohor Idrisi (Agriculture and Codes)
Professor Ekmeleddin Ihsanoglu (History of Science)
Dr Abdul Nasser Kaadan (Medicine)
Dr Munim Al-Rawi (Geology)
Dr Rabah Saoud (Architecture and Town Planning)
Professor Nil Sari (Ottoman Medicine)
Professor Aydin Sayili (Muslim Observatories)
Dr Ibrahim Shaikh (Surgery)
Professor Sevim Tekeli (Engineering and Mapping)
Dr Emily Winterburn (Astrolabes)
Dr Salah Zaimeche (Muslim Science and Geography)

CHIEF EDITOR

Professor Salim T S Al-Hassani, University of Manchester, Chairman of Foundation for Science, Technology and Civilisation (FSTC)

CO-EDITOR AND PRODUCTION MANAGER

Elizabeth Woodcock, 1001 Inventions Ltd

CO-EDITOR

Dr Rabah Saoud, Muslim Heritage Consulting (MHC)

RESEARCHERS

Dr Salim Aydüz, FSTC
Wai Yin Chang, MHC
Mona Kamal, MHC
Margaret Morris, FSTC
Dr Rabia Yousef, MHC

CONSULTANTS

Dr Subhi Al-Azzawi, Architect, Kent
Dr Farooq Bajwa, FSTC, London
Dr Ruth Barnes, Ashmolean Museum, Oxford
Dr Anne-Maria Brennan, London South Bank University
Professor Charles Burnett, The Warburg Institute, London
Professor Sami Chalhoub, Institute of History of Arab Science, University of Aleppo
Professor Nabila Dawood, Centre for the Study of Arab & Muslim Heritage, University of Baghdad
Professor Mohammad El-Gomati, University of York
Dr Abdul Nasser Kaadan, Institute of History of Arab Science, University of Aleppo
Mr Paul Keeler, Golden Web, Cambridge
Dr Mustafa Mawaldi, Institute of History of Arab Science, Aleppo
Mr Peter Raymond, MBE, Manchester
Professor Emily Savage-Smith, University of Oxford
Dr Rim Turkmani, Imperial College and Medicine, London

IMAGE SOURCING

Samia Khan, MHC
Nosheen Ladha, MHC

DESIGN & LAYOUT

Mukhtar Sanders, Inspiral Design

ILLUSTRATORS

Ali Amro, MHC
Sayed Al Hashmi, IIIG

COPY-EDITOR

Nighat Bajwa
Carolyn Garwes

INDEXER

Carolyn Garwes

PROOFREADER

Dr Ranjan Chaudhuri

FIRST EDITION PUBLISHED BY FSTC LTD

• 27 Turner Street, Manchester
M4 1DY, Great Britain

SECOND EDITION PUBLISHED BY FSTC LTD

ISBN-13: 978-0-9552426-1-8

British Library CIP Data:

Al-Hassani, Salim T S.
1001 Inventions: Muslim Heritage in Our World
1. Islamic Science-History.
2. Technology-Civilisation.
I. Title.
509.53 / HAS

US Library of Congress CIP Data:

Al-Hassani, Salim T S.
1001 Inventions: Muslim Heritage in Our World / Salim T S Al-Hassani
Includes manuscript list.
1. Technology-Islam-History.
2. Science-Civilisation.
I. Title
Q1-391-995H37 2005

Printed and bound by Mega Basim in Istanbul, Turkey

Preface

THE FIRST EDITION OF THIS BOOK was part of the *1001 Inventions* project, comprising a touring exhibition, book, teachers' pack, educational posters and website www.1001inventions.com.

The resounding success of this project saw the book selling out within three months. This revised second edition provides an opportunity to improve the content by introducing new material, images and clarifying ambiguities. For the benefit of the academic reader there is a fuller reference list of authoritative manuscripts and their locations. An expanded glossary of Arabic and other relevant terms have also been added and the index extended.

There is a worldwide demand for the *1001 Inventions* project, and we are now translating the book into other languages and developing the exhibition to tour the world.

The popular and specialist media, the public, the education community and academe have praised the project and from various surveys conducted on the impact of the *1001 Inventions* project, it seems that it has impinged positively upon the public mind. Thousands have re-evaluated their perception of the so-called 'Dark Ages' and the role of Muslim civilization in laying the foundations of modern science and technology. The question very frequently asked is why it is that none of this material is found in the UK National Curriculum?

The *1001 Inventions* project has proved its effectiveness to stimulate young people's interest in science and technology, to instil confidence, and to provide positive Muslim role models for evolving Muslim identities, especially in the West.

Great Muslim men and women of the past - mathematicians, astronomers, chemists, physicians, architects, engineers, economists, sociologists, artists, artisans, and educators - expressed their religiosity through beneficial contributions to society and humanity. They did so with open-mindedness and, in many instances, positively and constructively worked alongside non-Muslims. This track record of cooperation over the centuries, although deeply rooted within early Muslim society, seems to have been forgotten. The *1001 Inventions* project, indirectly, is tapping into that tradition by seeking to develop a better understanding between peoples and cultures.

Some terminology used here can have a wide meaning, used in specific contexts, and should not be taken literally. For example, in this book the word invention can also mean innovation, embracing new discoveries, concepts, methods, devices and machines which were hitherto unknown. It also includes items such as chess, the waterwheel and paper, which were known before Islam but brought to Europe by Muslims.

It is encouraging to see Muslim heritage at the forefront of media coverage, documentaries, articles, festivals, books and academic projects. In this context, I would like to take this opportunity to express my deep gratitude to the endless number of supporters of this project, in particular to those who have joined the global community of Muslim Heritage since the launch of the first edition. For new readers, I wish them an enjoyable and stimulating journey of discovery.

PROFESSOR SALIM T S AL-HASSANI
Chief Editor & Chairman of FSTC

Foreword

I WELCOME THIS FASCINATING BOOK as a significant contribution to a wider understanding of science and technology within Muslim civilization, and of our debt in modern societies to this particular tradition. Within any particular culture, such as the Western and Anglo-centric tradition, it is all too easy to forget or downplay the complex history of the development of scientific ideas and technological inventions. Science and technology, in some shape or form, exists and develops within all types of societies and in the context of all shades of religious belief. Ultimately, it matters not exactly by whom, or exactly when, a particular discovery or invention was made.

This book, however, is a welcome reminder that Muslims have made many important and far-reaching contributions to the development of our shared scientific knowledge and our technologies. I hope it will be an inspiration to people of both Muslim and other faiths, and indeed to those with no religious belief, demonstrating the ways in which science helps reveal the wonders of the natural world, and through which technology makes such a contribution to the ways in which we can work together with each other.

SIR ROLAND JACKSON
Chief Executive, The British Association for the Advancement of Science

Contents

Chapter 5: Town

Chapter 6: World

Chapter 7: Universe

Reference

Introduction

THE DEVELOPMENT OF THIS BOOK tells an interesting story. In 1975, Lord B V Bowden, the Principal at the time of the University of Manchester Institute of Science and Technology (UMIST), became fascinated by the manner in which the Muslims managed a domain that stretched from China across to, and including, Spain for so many centuries. Of particular interest was how they introduced the concept of 'indexation' in combating inflation, which was rampant in the Roman Empire. He announced in the House of Lords that in order to guide the UK's economy, then riddled with inflation, we should learn from the Muslims' experience and consider the economic principles laid down some one thousand four hundred years ago in the Quran.

He set up an Institute for the History of Muslim Science, Technology and Commerce, recruiting myself and a few professors from UMIST and the Victoria University of Manchester, and we were augmented by dignitaries. Although this initiative did not thrive for long, it gave me the opportunity to encounter historians and scholars outside my engineering discipline and, more significantly, it revealed to me the frightening level of their ignorance of the traditions and beliefs of other cultures. Lord Bowden subsequently passed away in 1989, and with him went that Institute.

It was not until 1993 when Professor Donald Cardwell, Head of the Department of History of Science and Technology, and the Founder of the Museum of Science and Technology in Manchester, presented me with a challenge. Much in the spirit of Lord Bowden he said: 'Salim, [my first name] you should by now know there are a thousand years missing from the history of engineering, a period we call the Dark Ages. Most of the missing knowledge is contained in Arabic manuscripts filling the cellars of many famous libraries. You are a distinguished Professor of Engineering at a prestigious university and you know the Arabic language. Therefore, you are best suited to do something about filling this gap.'

That wake-up call propelled me to follow a line of inquiry that eventually changed my life. That was when the story of this book began.

Before taking this challenge, however, I looked up various books and journal papers and consulted numerous friends. Book after book, journal after journal, all pointed to this incredible gap. Take, for instance, this typical popular book at the time: *The People Who Made Technology From Earliest Times to Present Day* by Anthony Feldman and Peter Ford, published by Aldus Books Ltd in London 1979. The authors explain that the book gives, in chronological order, humanity's scientific and technological progress from invention of movable type to the discovery of penicillin. The names of the great inventors, to whom they devote short chapters, follow in chronological order like this: Empedocles (c.490-430 BCE), Democritus (460-370 BCE), Hippocrates (460-377 BCE), Aristotle (383-322 BCE), Archimedes (287-212 BCE), Johannes Gutenberg (1400-1468 CE) followed by others like Da Vinci, etc.

The remarkable jump of one thousand six hundred years from the time of Archimedes to Johannes Gutenberg was amazing but troubling. Further reading of other books revealed that the whole period, 450-1492 CE, is in fact passed over as 'The Dark Ages.' It is altogether ignored as far as science and civilization are concerned, termed variously as 'a middle age', an intermediary period, a uniform bloc, 'vulgar centuries' and, most disconcerting of all, 'obscure time.' Some books include

a bit more on the Romans, but still leap over one thousand years. More disquieting were the gaps in school textbooks and other sources of learning, which form the views and perceptions of pupils on other cultures aside from their own.

Later that same year, on the 27 October 1993, I attended an inspiring lecture by HRH Prince Charles at the Sheldonian Theatre, Oxford, entitled *Islam and the West*. Addressing a galaxy of eminent scholars in one of the strongholds of Orientalism, his speech was received like fire in dry woods. The eye-opening extract below reinforced my findings:

> *If there is much misunderstanding in the West about the nature of Islam, there is also much ignorance about the debt our own culture and civilization owe to the Islamic world. It is a failure, which stems, I think, from the straight-jacket of history, which we have inherited. The medieval Islamic world, from central Asia to the shores of the Atlantic, was a world where scholars and men of learning flourished. But because we have tended to see Islam as the enemy of the West, as an alien culture, society, and system of belief, we have tended to ignore or erase its great relevance to our own history.*

All students are trained to think critically; yet when faced with the darkness of ten centuries in Europe, they are told things appeared, as if by miracle, all at once during the Renaissance. This defies logic. Things, such as discoveries, inventions and further developments that alter the course of humanity, as any scientist knows, do not appear by chance! Continuity is fundamental, especially in the birth and rise of the sciences; it is almost so in every other field of study.

A couple of years later and just before passing away, Professor Cardwell arranged for me to give a presentation at the esteemed Literary and Philosophical Society, entitled the *Muslim Contribution to Science and Technology*. The amount of amazement and surprise expressed by the audience, on the little I had to say, reinforced the statement of Prince Charles. From then on, whenever I lectured on the topic I felt like a one-eyed man amongst the blind. Of special excitement was the fascination of young people in the subject of knowing where our present civilization came from.

The ambition to write a book on the subject was pushed aside by the reality of being a Professor of Mechanical Engineering, in a university world invaded by market forces with all the pressures of lecturing, researching, publishing, fund raising, administration, and running two consulting companies. The practical solution was to hire historians and initiate undergraduate projects on the virtual reconstruction of ancient machines. This, together with the support of like-minded academics and professionals, saw the emergence of the Foundation for Science, Technology and Civilisation. The would-be book instead began to take shape in the form of a website, www.MuslimHeritage.com, which attracted excellent peer reviewed papers from renowned writers and researchers.

Very quickly, the website became the first destination and source of information for many institutions of learning, schools, media groups and young people from all over the English speaking world. It now attracts more than 50,000 daily page views.

The subject of Muslim contributions to science and civilization attracted much popular interest immediately after the (now known as) 9/11 attack (11 September 2001) on the World Trade Center twin towers. What was amazing was a daring speech given, two weeks later, by one of the most famous businesswomen and historians at the time, Ms Carleton Fiorina, Chief Executive Officer

of Hewlett-Packard Corporation. At a meeting of all the corporation's worldwide managers, on 26 September 2001, Ms Fiorina announced:

> *There was once a civilization that was the greatest in the world. It was able to create a continental super-state that stretched from ocean to ocean and from northern climes to tropics and deserts. Within its dominion lived hundreds of millions of people, of different creeds and ethnic origins.*
>
> *One of its languages became the universal language of much of the world, the bridge between the peoples of a hundred lands. Its armies were made up of people of many nationalities, and its military protection allowed a degree of peace and prosperity that had never been known. The reach of this civilization's commerce extended from Latin America to China, and everywhere in between.*
>
> *And this civilization was driven more than anything, by invention. Its architects designed buildings that defied gravity. Its mathematicians created the algebra and algorithms that would enable the building of computers, and the creation of encryption. Its doctors examined the human body, and found new cures for disease. Its astronomers looked into the heavens, named the stars, and paved the way for space travel and exploration. Its writers created thousands of stories. Stories of courage, romance and magic. Its poets wrote of love, when others before them were too steeped in fear to think of such things.*
>
> *When other nations were afraid of ideas, this civilization thrived on them, and kept them alive.*
>
> *When censors threatened to wipe out knowledge from past civilizations, this civilization kept the knowledge alive, and passed it on to others.*
>
> *While modern Western civilization shares many of these traits, the civilization I'm talking about was the Islamic world from the year 800 to 1600, which included the Ottoman Empire and the courts of Baghdad, Damascus and Cairo, and enlightened rulers like Sulayman the Magnificent.*
>
> *Although we are often unaware of our indebtedness to this other civilization, its gifts are very much a part of our heritage. The technology industry would not exist without the contributions of Arab mathematicians.*

When I gave a presentation in the city of Watford, a few years ago, the chief guest Lady Mayoress expressed dismay at why the Muslims do not use this language, referring to our common heritage in science and technology for dialogue, instead of the language of religious and political differences, and why is it that we do not find this in the National Educational Curriculum?

A number of colleagues, well established in the subject, began a lecturing campaign in Britain, Europe and abroad. A large number of people from all walks of life derived pleasure and inspiration from this knowledge. Presentations to the younger generation, especially the ones I gave to the Youth NGOs at the European Parliament in Brussels, sparked enormous interest in science and technology, and especially in the lives of Muslim pioneers in chemistry, physics, medicine, biology, algebra, engineering, architecture, art, agriculture and in numerous manufacturing industries who have impacted so positively on our modern civilization.

Young Muslims, however, find in such knowledge a new identity, allowing them to be European whilst at the same time Muslims. They find exciting role models, male and female, for innovation and invention, and begin to recognize that these pioneers, unlike many today, had expressed their religious commitment and faith through deeds useful to society, be it Muslim or non-Muslim, and that ineptness, looking inwards and reliance on governments to develop society was not their tradition.

Good TV series began to emerge, like the most fascinating one presented by Adam Hart-Davis (BBC2). His *What the Ancients Did for Us*, devoted a whole episode to *What the Islamic World Did for Us*, showing reconstructed machines, devices and products. Other shows followed, revealing the scientific impact of Muslim Spain on the rest of Europe. This is an encouraging movement, but negative public perceptions of Muslim civilization and tradition are likely to remain as long as there is no available popular digest or school text on the subject to fill this void.

At a time when greater cultural understanding is paramount, it became imperative to take the resounding success of the website to a new dimension. This evolved into an interactive, educational, non-political and non-religious touring exhibition on the theme of Muslim contributions to civilization. Entitled *1001 Inventions: Discover the Muslim Heritage in our World*, this enjoys the benefit of being accompanied by this book, a teacher's pack, posters and a brand new dedicated website. This book is thus one of the much laboured-over fruits of the *1001 Inventions* project. Its painstaking completion is an achievement of no single individual, but of all those mentioned on the contributors, acknowledgements and sponsors pages.

This book identifies, in an enjoyable, easy-to-read format, aspects of our modern lives that are linked with inventions by Muslims or were inspired by Islam. The book is divided into seven chapters which mirror the seven zones of the *1001 Inventions* exhibition: home, school, hospital, market, town, world and universe. Each zone represents a sphere of our lives that has benefited from Muslim inventions.

Amongst the main objectives we hope to fulfil are to:

- Raise awareness of the thousand years (7^{th}–17^{th} century) of Muslim heritage.
- Generate understanding and appreciation of Muslim contributions towards the development of contemporary science and technology worldwide.
- Inspire young people from both Muslim and non-Muslim backgrounds to find career role models in science and engineering.
- Promote the concept of scientific and technological innovation as a positive and constructive channel of personal expression of beliefs, as an alternative to religious isolationism and extremism.
- Bridge themes in the history of science, industry and arts with contemporary developments.

We very much hope that with the assistance of the readers we can achieve some, if not all, of these noble objectives.

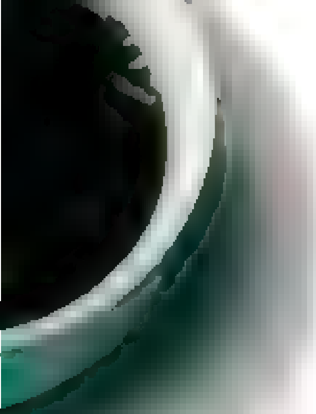
PROFESSOR SALIM T S AL-HASSANI
Chief Editor & Chairman of FSTC

01 HOME

'He is happiest, be he King or peasant, who finds peace in his home.'

Johann von Goethe





On the Coffee Trail

1.6 BILLION CUPS OF COFFEE are drunk worldwide everyday. That's enough to fill nearly three hundred Olympic-sized swimming pools everyday, and if you don't have a jar of coffee in your kitchen, you're probably in a minority. Coffee is a global industry and is the second largest commodity-based product; only oil beats it.

'Coffee makes us severe, and grave, and philosophical.'

Jonathan Swift

More than twelve hundred years ago hardworking people fought to stay awake without this stimulant, until a herd of curious goats and their watchful master, an Arab named Khalid, discovered this simple, life changing substance. As his goats grazed on the Ethiopian slopes, he noticed they became lively and excited after eating a particular berry. Instead of just eating the berries they were taken and boiled to create *al-qahwa*.

Sufis in Yemen drank *al-qahwa* for the same reasons we do today, to stay awake. They could now concentrate during late night *Thikr* (prayers in the remembrance of Allah). It spread to the rest of the Muslim world through travellers, pilgrims and traders, reaching Mecca and Turkey in the late 15th century and Cairo in the 16th century as a popular beverage.

The first coffee house in Europe appeared in Venice in 1645, after coffee came to Europe through trade with North Africa and Egypt. The Lloyds Coffee House in London (below), established in the late 17th century, was a meeting place for merchants and ship-owners. Coffee houses became forerunners of today's pubs. They were the places where the public discussed political affairs and also gave rise to the liberal movement.

Left to right: A goat herd in Ethiopia where coffee was first discovered; Lloyds Coffee House

It was a Turk named Pasqua Rosee, a merchant in 1650 CE, who first brought coffee into the UK, selling it in a coffee house in George yard, Lombard Street, London. Eight years later another cafe called 'Sultaness Head' was opened in Cornhill. Lloyds of London, today a famous insurance company, was originally a coffee shop called 'Edward Lloyds Coffee House'. By 1700, there were about five hundred coffee houses in London, and nearly three thousand in the whole of England. They were known as 'penny universities' because you could listen and talk with the great minds of the day for the price of a coffee, a penny, which was then 1/240th of a pound.

The consumption of coffee in Europe was largely based on the traditional Muslim preparation of the drink. This entailed boiling the mixture of coffee powder, sugar and water together, which left a coffee residue in the cup because it was not filtered. However, in 1683 a new way of preparing and drinking coffee was discovered, and it became a coffee house favourite.

Cappuccino coffee was inspired by a certain Marco d'Aviano, a priest from the Capuchin monastic order, who was fighting against the Turks besieging Vienna in 1683. Following the retreat of the Turks, the Viennese made coffee from abandoned sacks of Turkish coffee. Finding it too strong for their taste, they mixed it with cream and honey. This made the colour of coffee turn brown, resembling the colour of the Capuchins' robes. The Viennese then named it cappuccino in honour of the Marco D'Avianos order and since then cappuccino has been drunk for its enjoyable, smooth taste.

'Coffee is the common man's gold, and like gold it brings to every person the feeling of luxury and nobility.'

Sheikh 'Abd al Kadir who wrote the earliest known history of coffee manuscript in 1588

16th century manuscript showing a coffee house with men drinking coffee

Clocks

WHATEVER WE DO, wish, hope, dream or fear, time will always go on, with or without us. Whether it is an examination we dread taking, an important interview or a birthday, there will be a time when it begins and ends.

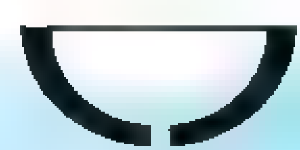
From the first sundial, people have wanted to record time. Now we can have silent, digital timepieces as well as the tick-tock of modern clocks. Their ancestors were the drip-drop of the clepsydra and of water clocks. The clepsydra, a simple vase marked with divisions that measured water flowing out of a small spout near the base, was used in Egypt before 1500 BCE.

Another ancient water timing device is from India, and is called *ghatika yantra*. It consists of a small hemispherical bowl (made of copper or a coconut) with a small hole in its base. Floated in a larger pot of water, the bowl would gradually fill and sink. When it reached the bottom, an audible thud alerted the timekeeper who would raise it up to start the process again. This became very popular in Buddhist and Hindu temples, and later was very widely used in Indian Muslim mosques.

Our story begins with 13th century water clocks and an ingenious man called al-Jazari from Diyarbakir in South East Turkey. He was a pious Muslim and a highly skilled engineer who gave birth to the concept of automatic machines. He was inspired by the history of machines and the technology of his predecessors, particularly the Ancient Greek and Indian scientific inventions.

By 1206, al-Jazari had made numerous clocks of all shapes and sizes while he was working

From left to right: The evolution of recording time from sundials, clepsydras, water clocks, weight-drive grandfather clocks to today's digital clocks.



An Indian ghati – as the bowl fills with water it sinks to the bottom of the tank after a pre-set time interval depending on the weight and size of the bowl and size of the hole. As it hits the bottom, it makes a thud and alerts the timekeeper who lifts it to start the process again.

Like others in his day, al-Jazari heeded the Arab proverb: 'Time is like a sword: unless you cut with it, it will cut you.'

for the Urtuq kings of Diyarbakir. The then king, Nasir al-Din, son of the great Saladin, said to him, 'You have made peerless devices, and through strength have brought them forth as works; so do not lose what you have wearied yourself with and have plainly constructed. I wish you to compose for me a book which assembles what you have created separately and brings together a selection of individual items and pictures.'

The outcome of this royal urging was an outstanding book on engineering called *The Book of Knowledge of Ingenious Mechanical Devices*. This book became an invaluable resource for people of different engineering backgrounds, as it described fifty mechanical devices in six categories, including water clocks.

Just as we need time today to structure our lives, so did Muslims over seven hundred years ago, and al-Jazari was keeping to a long Muslim tradition of clock making. They knew that time could not be stopped, that we are always losing it, and that it was important to know the time so it could be used well through doing good deeds. Muslims also needed to know when to pray at the right times each day. Mosques had to know the time so they could announce the call to prayer. Important annual events, like when to fast in Ramadan, celebrate *Eid* or go on pilgrimage to Mecca also had to be anticipated.

This inspiration meant that the 'peerless devices' to which Saladin's son referred included the Elephant Clock. As well as telling the time, this grand clock was a symbol of status, grandeur and wealth, while also incorporating the first robotics with moving, time-telling figures.

'I (Allah) swear by the time, surely man is in loss, save those who believe and do good works and (join together) in the mutual teaching of Truth, and of Patience and Endurance.'

Quran (103)

Below left: The remaining front wall from a water clock at Bou Inania *madrasa* (the first Big Ben) built circa 1356 CE in Fez, Morocco.

Al-Jazari's 13th century manuscript showing the Elephant Clock.

The Elephant Clock

About eight hundred years ago, al-Jazari built this elaborate clock in order to celebrate the diversity of mankind and the universal nature of Islam. At this time, the Muslim world spread from Spain to Central Asia. So, to reflect this scope, al-Jazari used Greek (Archimedes) water principles combined with an Indian water timing device (*ghoti*), an Indian elephant, an Egyptian phoenix, Arabian figures, a Persian carpet and Chinese dragons. The figure on the top of the castle is thought to be Saladin included as a sign of respect to the great leader. The features also symbolized countries and trade, and each animal had a myth associated with it: the elephant was a symbol of royalty, the phoenix of rebirth and life, and the dragon of power and impregnability.

As well as celebrating the diversity of his world, he also wanted to develop machines with a better design and greater output than his predecessors. So although the clock was awe-inspiring to look at, its brilliance was really seen in adapting the perforated water bowl (Archimedian/Indian *ghoti*), so that it oscillated about its rim rather than sinking vertically. This was central to the whole timepiece.

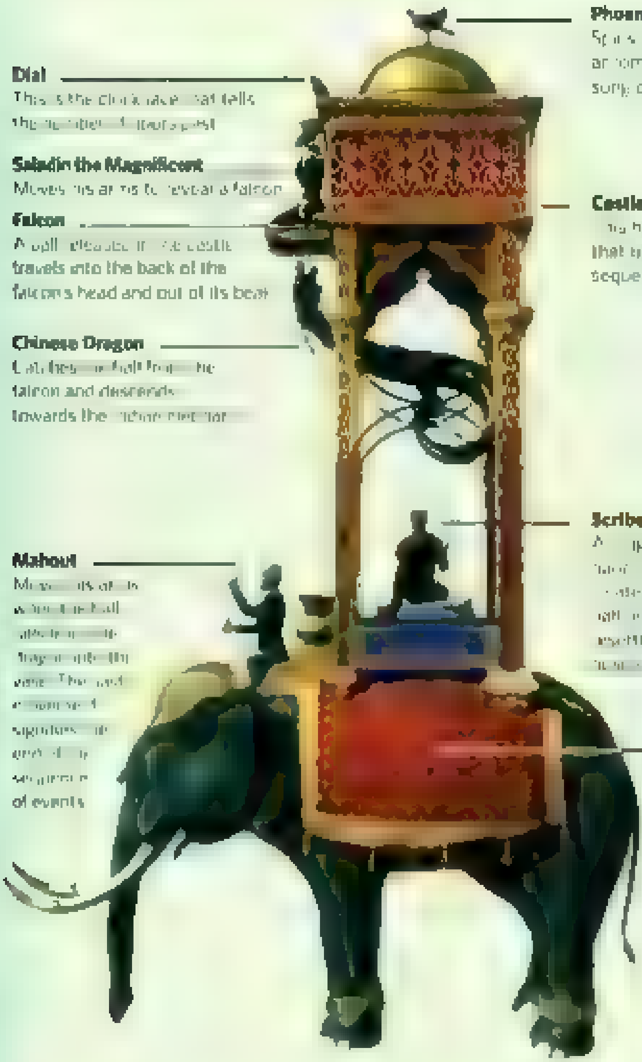
The bowl had a hole in it and floated in a water tank inside the elephant's belly. Gradually, it filled with water, slowly sank and tilted simultaneously, pulling three ropes attached to it. The three ropes then set off mechanisms that controlled thirty balls that were released individually, the action of the dragons, and the rotating scribe.

The ingenuity of al-Jazari was in the precision with which he measured the hole in the oscillating bowl: it took exactly half an hour for the bowl to fill, sink and begin again.

When the bowl sank it caused a flute noise, like a bird's song, and the phoenix would spin. The released ball would make the dial behind Saladin turn, and Saladin would move from side to side, 'deciding' which falcon would release which ball. The ball then dropped into the dragon's mouth and it bent down placing the ball into the vase behind the Mahout, the elephant rider. That made him move his arms and a cymbal sounded as the ball went into the vase. The circles on the dial behind the top of Saladin's figure told the time, as they filled half-by-half as each half-hour passed. This sophisticated series of actions and reactions continued every half-hour throughout the day.

The clock would be 'reset' twice a day, at sunrise and sunset. This meant restoring the thirty metal balls to their original position and maintaining the water level, as the rate of flow changed daily because the span of an 'hour' varied in length from day to day as periods of darkness and daylight altered.

The Workings of the Elephant Clock

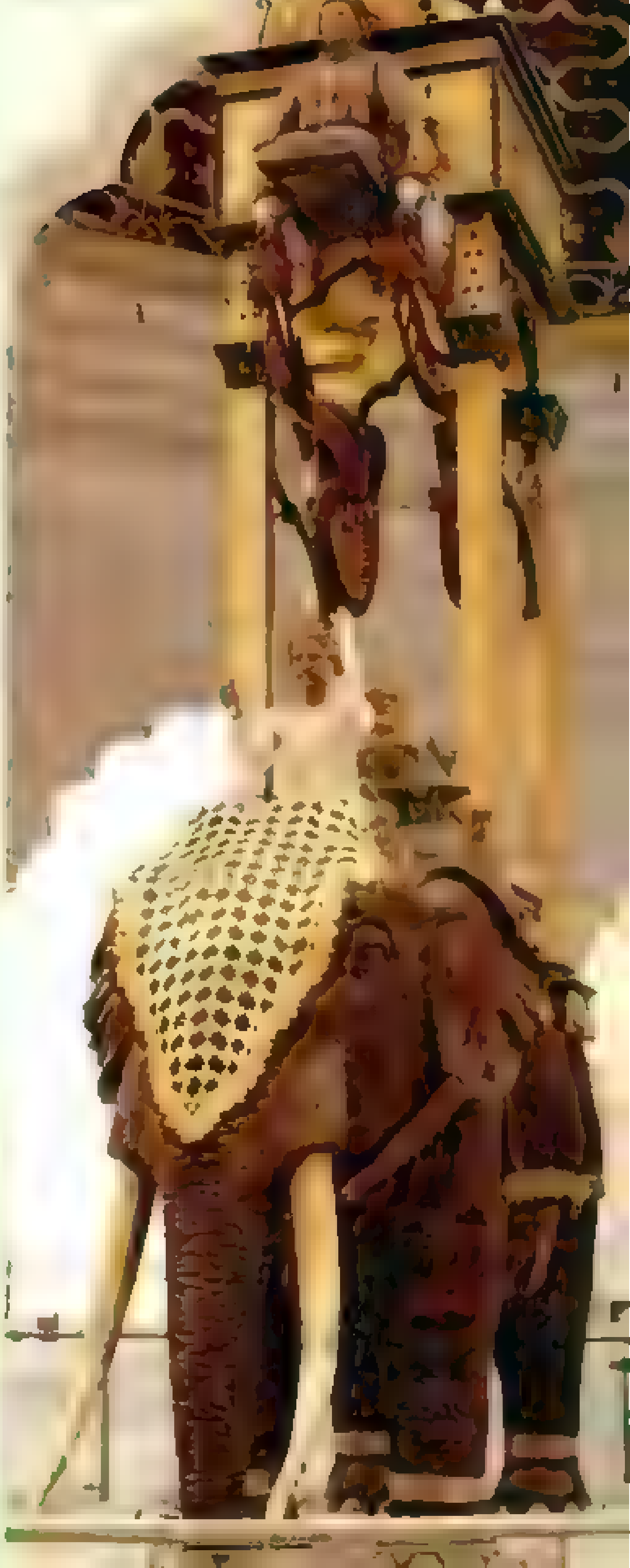


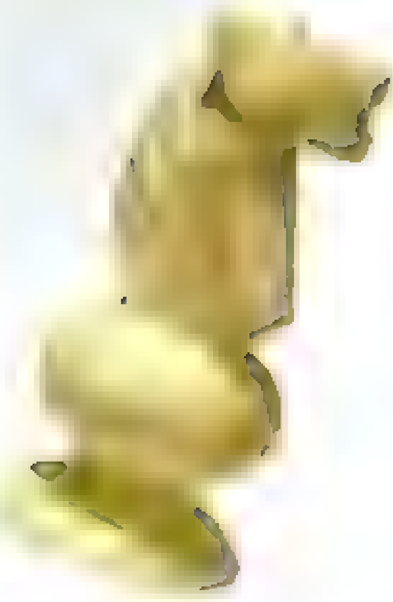
metres wide

4.5 metres long

the diversity of the world

The Elephant Clock as reconstructed in the Ibn Battuta Mall, Dubai.





Chess

STEAM RISES FROM THE HOT POOLS of Budapest city's outdoor baths, hanging above gathering crowds as they crouch low over marble chessboards. In China, chessboards are laid out in the parks, as they are in Central Park, New York. Chess is a game of mental combat played on sixty four squares with thirty two pieces by most nationalities. Despite its size and unassuming appearance, the number of possible games that can be played far exceeds the number of atoms in the universe.

The stories, figures and individuals surrounding chess give it a mysterious dimension and its definite origins remain unknown. It came from either India or Persia. In the 14th century, Ibn Khaldun connects chess to an Indian named Sassa ibn Dahir, an eminent man of wisdom.

There was an ancient Indian game called *Chaturanga*, which means 'having four limbs', probably referring to the four branches of the Indian army of elephants, horsemen, chariots and infantry. *Chaturanga* wasn't exactly chess but a precursor to the chess of today.

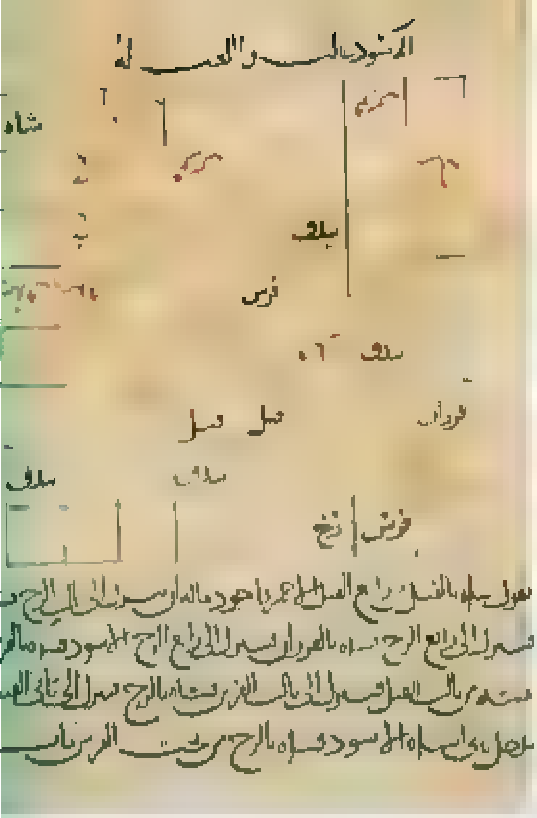
A 14th century Persian manuscript describes how an Indian ambassador brought 'chess' to the Persian court, from where it was taken to Europe by Arabs going to medieval Spain.

Before it reached Europe, the Persians modified the game into *chatrang*, using it in their war games. Arabs came into contact with chess, or *Shatranj* as it was then called, in Persia and it was absorbed into their culture.

At that time, the playing pieces were *Shah* as king; *Firzan* was a general, and became a queen in modern times; *Fil* was an elephant that became the bishop; *Faras* was the horse; *Rukh* was a chariot that is now the castle or rook; and *Baidaq* is the foot soldier or pawn.

It was very popular with the public as well as the nobles and the Abbasid caliphs particularly loved it. The great masters, though, were al Suli, al Razi, al Aadani and Ibn al Nadim. Russian grandmaster Yuri Averbakh played an astonishing move in one of his championship games, which he won. Many thought this to be an ingenious new idea but it was actually devised well over a thousand years ago by al Suli.

From left to right: A Muslim and Christian playing chess in a tent, from King Alfonso X's *Libros del Axedrez*, 13th century; two modern day chess players; chess players taken from a Persian treatise on chess in the second half of the 16th century.



Early 10th century chess table miniature from Abu Bakr al-Suli's *Ajmalaħah Kitab al-Shatranj*. The Arabic says "The black is winning and it is his turn to play" so we're not sure whether this is a game through [illegible] instruction that day of how to play.

Kempelen's Iron Muslim 'robot' (1769) had a chessmaster inside the cabinet, who played skilfully and beat other master players of the day

Arab 'grandmasters' wrote copiously on chess, about its laws and strategies, and these spread all over the Muslim world. There were books on chess history, openings, endings and problems. *Book of the Examples of Warfare in the Game of Chess*, written around 1370, introduced for the first time the chess game 'Blind Abbess and Her Nuns'.

The whirlwind Ziryab, a great musician and trendsetter, brought chess, as it was now called, to Andalusia in the early 9th century. The word 'Checkmate' is Persian in origin and a corruption of *Shahmat*, meaning '*the King is defeated*.'

From Andalusia, the game spread among the Christian Spanish and the Mozarabs, and reached northern Spain over the Pyrenees, crossing the borders into southern France. The first European records to mention chess go back to 1058 CE, when the will of Countess Ermessind of Barcelona dedicated her crystal chess pieces to St Giles monastery at Nimes. A couple of years later Cardinal Damiani of Ostia wrote to Pope Gregory VII, urging him to ban the 'game of the infidels' from spreading among the clergy.

Chess was also carried via the trade routes from Central Asia to the southern steppes of early Russia: 7th- and 8th-century Persian chess pieces have been found in Samarkand and Farghana. By 1000, chess had spread even further on the regularly used Viking trade routes as they carried it back to Scandinavia along with Arabian coins and statues of Buddha. Those trade routes meant that by the 11th century, chess had made its way right into Iceland, and an Icelandic saga written in 1155 talks of the Danish king, Knut the Great, playing the game in 1027.

By the 14th century, chess was accepted in Europe and King Alfonso X, nicknamed 'the Wise', produced the *Book of Chess and Other Games* in the 13th century. For the last eight centuries, there has been no looking back for chess and it has gone from strength to strength, producing a few funny sidelines, such as the robotic chessmaster of 1769.

Hungarian Wolfgang de Kempelen decided to give a gift to his Queen, Empress Maria Theresa, who was a chess fanatic. His gift was a robot machine called the Iron Muslim, later renamed Ottoman Turk, who played chess skilfully, beating high-ranked players of the day. It was the first Big Blue, except that it was more a mix of mechanical engineering and trickery. Inside, all cramped up, was a chessmaster who received none of the credit when he won. Instead, people travelled miles to marvel at the incredible turban-wearing robot. In fact, fifteen chess players inhabited it for eighty-five years, in the guise of an Ottoman 'Robotic' Turk.

Cleanliness

MEDIEVAL TIMES are often imagined as being smelly, dark, rough and unclean. Images of open sewers, disease and deformities spring into the imagination. In the 10th-century Islamic world though, the products found in bathroom cabinets and hygiene practices could compete with those we have today.

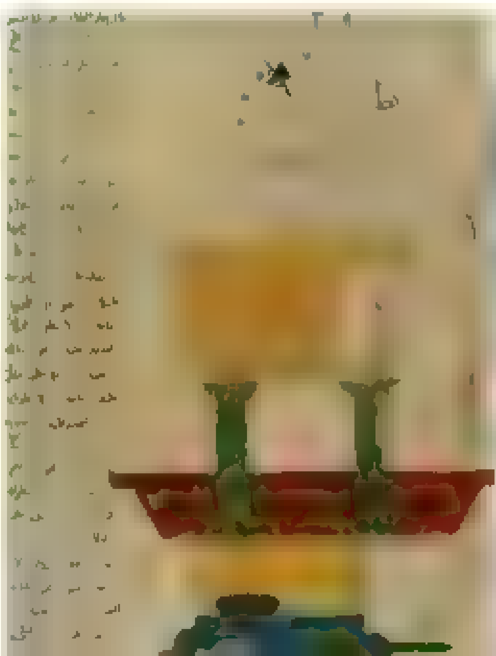
A Muslim's faith is based on purity and cleanliness, whether in its physical or spiritual form. They are requested to wash immediately before going to, and after getting up from, sleep as well as before and after eating. They are also ordered to wash five times a day, in ablution or what is known as *wudhu*, before they carry out their five daily prayers. On Friday, the Muslim holy day, it is essential for Muslims to take a bath before the main congregational prayer.

Back in the 13th century there was an outstanding mechanical engineer called al-Jazari who wrote a book called *The Book of Knowledge of Ingenious Mechanical Devices*. This book became an invaluable resource for people of different engineering backgrounds, describing mechanical devices, including *wudhu* machines. Look how elaborate and artistic this piece of ingenious engineering is compared to a tap and sink of today! This *wudhu* machine was mobile and brought in front of guests, appearing like a peacock on a tray. The guest would tap the head and water would ensue in eight short spurts, providing enough water for ablution. This method also conserved water. Some of these robots would have an additional action of providing you with a towel!

Muslims wanted to be really clean and not just splash themselves with water, so they made soap by mixing oil (usually olive oil) with *al-qali* (a salt-like substance). This was then boiled to achieve the right mix, left to harden and used in the *hammams* or bath houses.

'... When you rise up for prayer, wash your face, and your hands up to the elbows, and lightly rub your heads and (wash) your feet up to the ankles....'

Quran ([illegible])



From left to right: A manuscript showing al-Jazari's *wudhu* machine; a Muslim performing *wudhu* before prayers at a mosque

A recently discovered manuscript from the 13th century details more recipes for soap making, for example: take some sesame oil, a sprinkle of pot ash, alkali and some lime, mix them all together and boil. When cooked, pour the mixture into moulds and leave to set, producing a hard soap.

Soap had arrived in Europe with the crusaders' return, but hadn't been fashionable. By the 18th century, though, soap making was an important industry, especially in Syria. Coloured, perfumed toilet soap was produced as well as medicinal soaps.

Apart from scrubbing themselves clean, medieval Muslims also went to great lengths on their appearance, with physicians devoting books to beauty. One such man was al-Zahrawi, a famous physician and surgeon from Cordoba, southern Spain about whom you can read more in the Hospital chapter. He had been inspired by *hadiths*, or sayings, of the Prophet (pbuh) referring to cleanliness, management of dress, and care of hair and body. So, included in his medical book, called *al-Tasrif*, was a chapter in the nineteenth volume devoted completely to cosmetics. From a thousand years ago, this was the first original Muslim work in cosmetology, as al-Zahrawi considered cosmetics a definite branch of medicine, calling it *The Medicines of Beauty*.

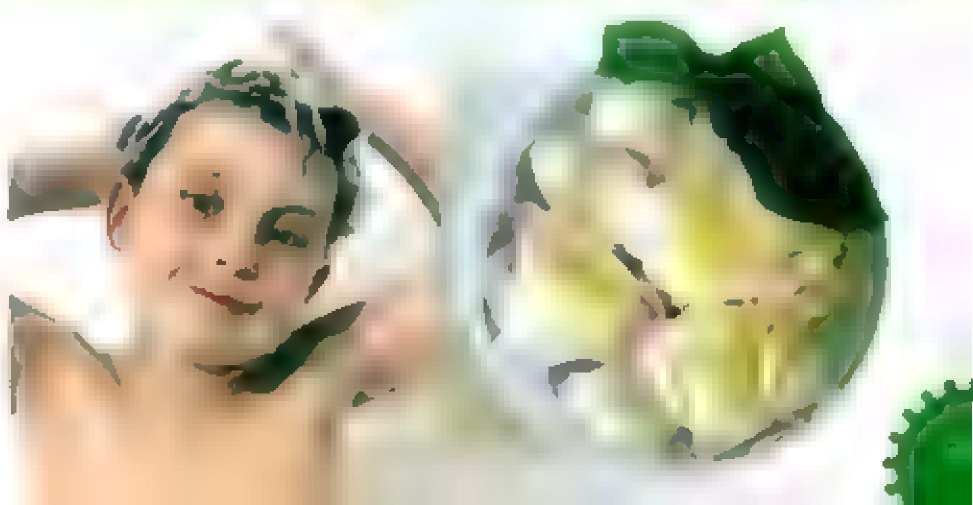
He described the care and beautification of hair, skin, teeth and other parts of the body, all within the boundaries of Islam. Gums were strengthened and teeth bleached, as dentistry was a common practice. He included nasal sprays, mouthwashes and hand creams and even suggested keeping clothes in an incense-filled nook so that they would have a pleasant fragrance for the wearer.

He elaborated on perfume and talked of perfumed sticks, rolled and pressed in special moulds, a bit like today's roll-on deodorants. He also named medicated cosmetics like hair removing sticks, as well as hair dyes that turned blond hair to black and lotions for straightening kinky or curly hair. The benefits of suntan lotions

Sake Dean Mahomed's Indian Vapour Baths on Brighton seafront

In the 1770s and '80s, Brighton was a blossoming beach resort and it was onto this scene that Sake (Sheikh, but because of accents this became Sake) Dean Mahomed arrived.

He was from a Muslim family in Patna, India, and in 1759 opened what was known as Mahomed's Indian Vapour Baths on Brighton seafront, the site of what is now the Queen's Hotel. These were like Turkish baths, but clients were placed in a flannel tent and received an Indian treatment of champi (shampooing) or therapeutic massage from a person whose hands came through slits in the flannel. This remarkable 'vapouring' and shampooing bath led him to receive the ultimate accolade of being appointed [illegible]



were also discussed as were their ingredients in detail, all amazing considering this was a thousand years ago.

Al-Kindi also wrote a book on perfumes called *Book of the Chemistry of Perfume and Distillations*. Born in Kufa, now in Iraq, he was best known as a philosopher, but was also a physician, pharmacist, ophthalmologist, physicist, mathematician, geographer, astronomer and chemist, and like many men today was involved with music, the manufacture of swords and even the art of cookery.

His book contained more than a hundred recipes for fragrant oils, salves, aromatic waters and substitutes or imitations of costly drugs. Initially, the more affluent in society wore these, until they became accessible for all. His 9[th] century book also described 107 methods and recipes for perfume-making, and even the perfume-making equipment needed, like the *alembic*, which still bears its Arabic name.

The centuries-old tradition of perfume-making is currently popular with many celebrities, and it was all made possible by Muslim chemists and their methods of distillation, as they were distilling plants and flowers, making perfumes and substances for therapeutic pharmacy.

These processes and ideas of the Muslims filtered into Europe in various ways, including via merchants and travellers, as gifts, and with crusaders. The BBC documentary *What the Ancients Did for Us: The Islamic World* said that the ideas of the Muslims eventually arrived at Haute Provence in the south of France, which has a perfect climate and the right kind of soil, and the perfume industry still flourishes here after seven hundred years.

Another important cosmetic in Islam is *henna*, known for its beautiful, intricate designs on elegant hands. With the spread of Islam, it reached different parts of the Muslim land, becoming an essential cosmetic ingredient

'Allah is Beautiful and He loves beauty.'

Prophet Mohammad (pbuh) narrated by Muslim (no.131)

'indigo and sesame oil ... gives protection against extremes of temperatures, it acts as an insect repellent, it gives bloom of neither a dark nor blue but something like a dark plum' Freya Stark writing on suntan lotions in Southern Gates of Arabia.

Indigo, from India, was known in ancient Egypt and by the Greeks. Muslim agronomists were the first to transplant, acclimatize and spread it all over their lands, especially in Africa, where it was grown along with cotton. Ibn al-Baytar, the 13[th]-century botanist, called it Niledj.

India, China, Mesopotamia and ancient Egypt had no olive oil, so sesame oil was the only alternative as sun protection, whereas the Touaregs and the Yemeni people protected their skin with indigo as a form of tanning.

Left to right: A woman having her hand decorated with henna; green henna powder sold by weight in Istanbul, Turkey

Prophet Mohammad (pbuh) and his companions dyed their beards, while women decorated their hands and feet and also dyed their hair like women of today. There are also particular *henna* related traditions within various countries: for instance, Berber tribes of Algeria and Morocco request that a bride apply *henna* for seven nights before going to her groom.

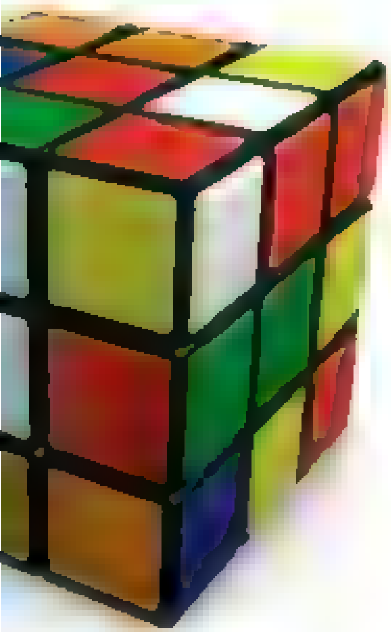
Modern scientists have found it to be anti-bacterial, anti-fungal and anti-haemorrhagic. It is useful in healing athletes foot, fungal skin infections and local inflammation. The leaves and seeds of the plant possess medicinal properties, and both act as cooling agents for the head and body. *Henna* also contains natural ingredients that are vital for hair nourishment.

For Muslims today, too, being clean and looking good holds just as much importance as it did back then. A person using all these thousand-year-old products today would not be out of place in a stylish restaurant in any cosmopolitan city in the 21st century.

Bad breath and food bits in your [illegible]th are not just off-putting, but [illegible] so in the 6th century, Pro[illegible]t Mohammad (pbuh) scrubbed [illegible] [illegible]th with a twig of Miswak before each prayer.

[illegible] company, Pharba B[illegible] Ltd, carried out experiments on Miswak ([illegible] Salvadora persica), and they found that it contains antibacterial substances which destr[illegible] harmful germs in the mouth that cause gum infections and tooth dec[illegible] [illegible] tests [illegible]nducted on the Miswak extract in Riyadh University, Saudi Arabia, and Indiana University, Indiana, USA, have confirmed its [illegible] inflammatory and antibiotic activities.

If no Miswak was at hand, Muslims ate cinnamon, nutmeg, card[illegible] and chewed on coriander leaves to get rid of bad breath from eat[illegible] [illegible] seasoned [illegible]th powdered clove[illegible]



Trick Devices

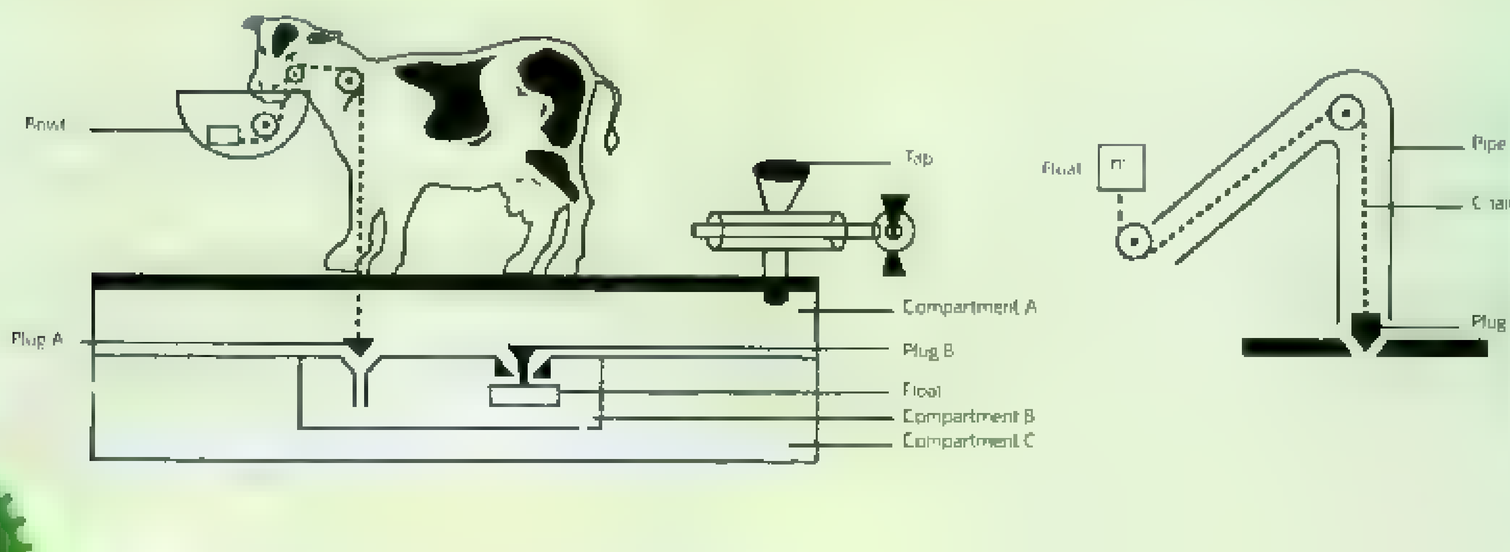
MAYBE YOU CAN HEAR the click clack of the metal balls swinging on wires as they knock each other rhythmically while you fiddle with a Rubik cube. Maybe it's not executive toys that interest you, but games and puzzles, whether for business or leisure will always be a source of fascination.

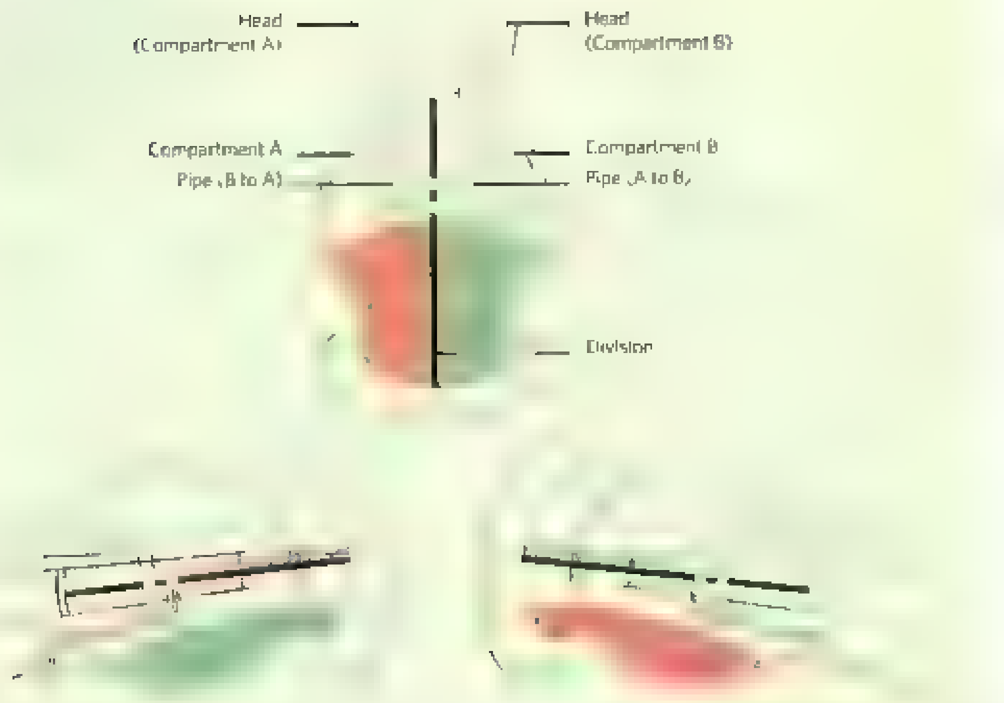
This sense of human wonderment was captured by three brothers in the 9th century. Muhammad ibn Musa ibn Shakir, Ahmed ibn Musa ibn Shakir and al-Hasan ibn Musa ibn Shakir were known as the Banu Musa brothers. They were part of the famous 'House of Wisdom', the intellectual academy of Baghdad in the 9th century, which you can read more about in the School chapter. As well as being great mathematicians and translators of Greek scientific treatises, they also invented fabulous trick devices which, some would say, are a precursor to executive toys. The brothers fed their peers' obsession by designing and making trick inventions and their *Book of Ingenious Devices* lists over a hundred of them. These were the beginnings of mechanical technology.

Like toys today, they had little practical function but these eleven-hundred-year-old mechanisms displayed amazing craftsmanship and knowledge.

Many of the mechanisms involved water, fake animals and sounds. For example, the drinking bull made a noise of contentment when it finished, as if its thirst had been satisfied. It did this using a series of filling chambers, floats, vacuums and plugs. So take a deep breath and see if you can follow the Banu Musa brothers' thinking on the diagram.

The Banu Musa Brothers 9th-century Drinking Bull robot





The inside of the Banu Musa brothers' trick Flask with Two Spouts.

Initially water comes from the tap into compartment A and then it's closed off. The bowl is then filled with water too. The float m (seen in the diagram opposite) rises with the level of water, pulling the plug out of the valve. Water drains from compartment A into compartment B. Float B rises with the water, pushing up plug B and allowing water to flow between the two compartments. When the air in compartment B is fully evacuated, a vacuum forms in compartment A since no air is allowed to flow into it. Water from the bowl is then drawn through the pipe and into A. Once all the water is gone from the bowl, air is sucked in so it appears that the bull is making a sound of contentment. Since no water is left in the bowl to keep the plug afloat, that particular plug closes, so only plug B is open to empty compartment A. Compartment B empties via a small hole between B and C. Air is allowed to flow freely from a hole on the side of compartment C. Now see if you can make it!

Highly complex and mind-twisting, this must have kept people enthralled for hours.

Another of the Banu Musa brothers' trick devices was a flask with two spouts. Coloured liquids were poured in each spout, but when it was time to pour, the 'wrong' colour came out of the 'wrong' spout. Like the magician who can make orange juice come out of his elbow, the brothers had an even better, and simple, intricate mechanism up their sleeves.

What they had done was to divide the jar in two vertically, with each section being totally separate from the other. Liquid came into the right side from the right funnel and into the left side by the left funnel and it couldn't leave this way again. Instead, another pipe had been inserted for the outflow. Of course, people observing couldn't see any of this and although it was simple, it still had impact and amazed them. The brothers' imagination for fun also seeped into designing fountains. So take a look at 'Fabulous Fountains' in the Town chapter.

'A joke is not a thing but a process, a trick you play on the listener's mind. You start him off toward a plausible goal, and then by a sudden twist you land him nowhere at all or just where he didn't expect to go.'

Max Eastman

Vision and Cameras

As a child did you ever wonder how we 'see'? Did you think that if you shut your eyes and you couldn't see anyone then no one could see you? Some ancient Greek scholars had less than conventional ideas of sight as well, and the first understanding of optics consisted of two main theories.

The first maintained that rays came out from our eyes, a bit like laser technology today, and these rays were cut off by the objects in our vision. So, sight was carried out through the movement of the rays from the eye to the object.

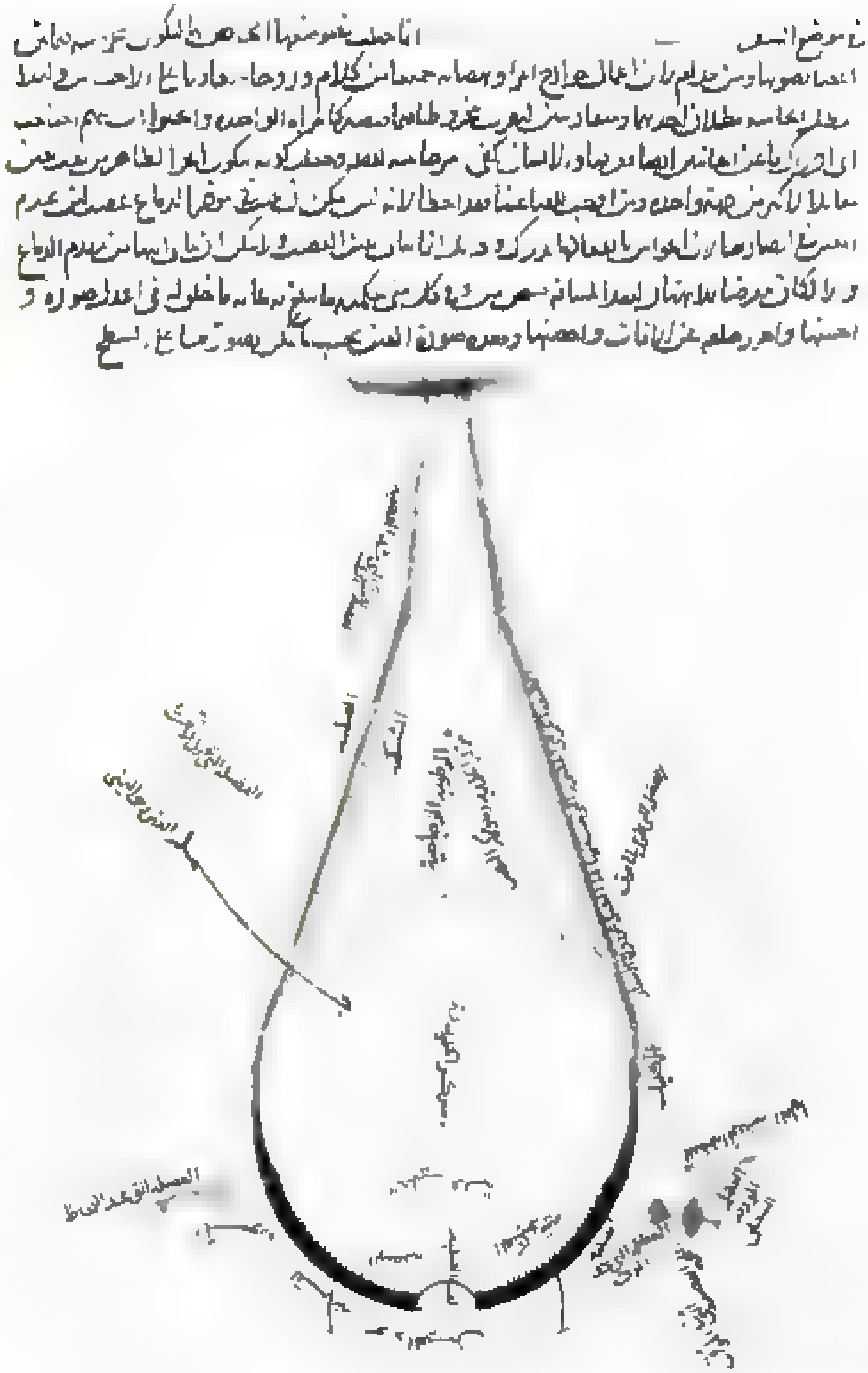
The second idea said that we see because something is entering our eye which represents the object. Aristotle, Galen and their followers rightly believed in this model but their theories were speculation and not backed up by experiments.

Ninth-century polymath al-Kindi first laid down the foundations of modern day optics by questioning the Greek theories of vision. He said that how we see, our visual cone, is not formed of discrete rays as Euclid had said, but appeared as a volume, in 3D, of continuous radiations.

Sixteenth-century Italian physician and mathematician Geronimo Cardano said al-Kindi was 'one of the twelve giant minds of history' because he discussed how light rays come in a straight line, sight with and without a mirror, and the influence of distance and angle on sight including optical illusions. Al-Kindi wrote two treatises on geometrical and physiological optics that were used by the English scholar Roger Bacon in the 13th century and the German physicist Witelo. According to Sebastian Vogl, a 20th century Danish scholar, Roger Bacon not merely

Far right: Roger Bacon's statue in the Oxford University Museum of N[illegible] inspired by the work carried out in optics by 9th century genius al-Kindi

The anatomy of the eye by 13th-century Kamal al-Din al-Farasi, based on Ibn al-Haitham's ideas. The Arabic text is referring to the role of the brain in interpreting the image on the retina of the eye



'He, Ibn al-Haitham, was the greatest Muslim physicist and student of optics of all times. Whether it be in England or far away Persia, all drank from the same fountain. He exerted a great influence on European thought from Bacon to Kepler.'

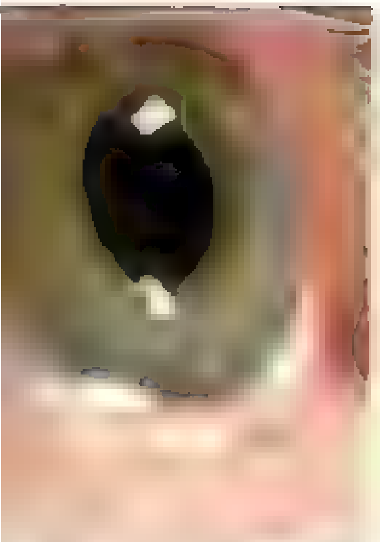
George Sarton in his *History of Science*

counted al-Kindi one of the masters of perspective but in his own *Perspectiva* he and others in his field referred repeatedly to his optics.'

The questioning originally begun by al-Kindi was built upon by al-Hasan ibn al-Haitham in the 10th century, who eventually explained that vision was made possible because of the refraction of light rays. Distinguished 20th-century science historian George Sarton said that the leap forward made in optical science was due to this man's work, which scientifically explained much of what we know today about optics.

In fact, a 10th century physicist, Ibn Sahl from Baghdad, had worked on light refraction by lenses before Ibn al-Haitham, although we're not sure that Ibn al-Haitham knew of Ibn Sahl's work. Al-Hasan ibn al-Haitham, usually called just Ibn al-Haitham and also known in the West as Alhazen, carried out meticulous experiments a thousand years ago, which enabled him to provide the scientific explanation that vision was caused by light reflecting off an object and entering the eye,

Below: Frontispiece taken from the 1572 Latin edition of *Book of Optics* by Alhazen (the Latin name for al-Hasan ibn al-Haitham).



'Light issues in all directions opposite any body that is illuminated with any light (and of course, also opposite any self-luminous body). Therefore when the eye is opposite a visible object and the object is illuminated with light of any sort, light comes to the surface of the eye from the light of the visible object.'

10th century Ibn al-Haitham from his Book of Optics

and he was the first to totally reject the theory of the Greeks.

Born in Basra, Iraq, he moved to Egypt on the invitation of its ruler to help reduce the effects of the Nile's flooding, and was the first to combine the 'mathematical' approach of Euclid and Ptolemy with the 'physical' principle favoured by natural philosophers. He said 'The knowledge of optics demands a combination of physical and mathematical study'.

He was also a mathematician, astronomer, physician and chemist, but his *Book of Optics* has formed the foundations for the science of optics. Famously known as *Magnum Opus*, it discussed the nature of light, the physiology and mechanism of sight, the structure and anatomy of the eye, reflection and refraction, and catoptrics.

He studied lenses, experimenting with different mirrors like flat, spherical, parabolic and cylindrical, concave and convex. He also treated the eye as a dioptric system, by applying the geometry of refraction to it. He brilliantly investigated the phenomenon of atmospheric refraction, calculating the height of the atmosphere to be ten English miles. This compares well with modern measurements of the troposphere, the lowest layer of the atmosphere, which measures about seven miles.

Ibn al-Haitham used experimental evidence to check his theories, which was unusual for his time because physics before him was more like philosophy, without experiment. He was the first to introduce experimental evidence as a requirement for accepting a theory, and his *Book of Optics* was actually a critique of Ptolemy's book *Almagest*. A thousand years on, this optics book is still quoted by professors training research students to be factual and not be swayed by opinions or prejudice. Some science historians believe that Snell's Law, in optics, actually resides in the work of Ibn Sahl and Ibn al-Haitham.

An artistic impression showing Ibn al-Haitham and his camera obscura in Cairo, Egypt.

The Camera Obscura

Like many eminent philosophers and mathematicians, Ibn al-Haitham was a keen observer. While in a room one day he noticed light coming through a small hole made in the window shutters. It fell onto the wall opposite and it was the half-moon shape of the sun's image during eclipses. He said: "The image of the sun at the time of the eclipse, unless it is total, demonstrates that when its light passes through a narrow, round hole and is cast on a plane opposite to the hole it takes on the form of a moon-sickle."

From these experiments, he explained that light travelled in a straight line and when the rays were reflected off a bright subject they passed through the small hole and did not scatter but crossed and reformed as an upside-down image on a flat white surface parallel to the hole. He then established that the smaller the hole, the clearer the picture.

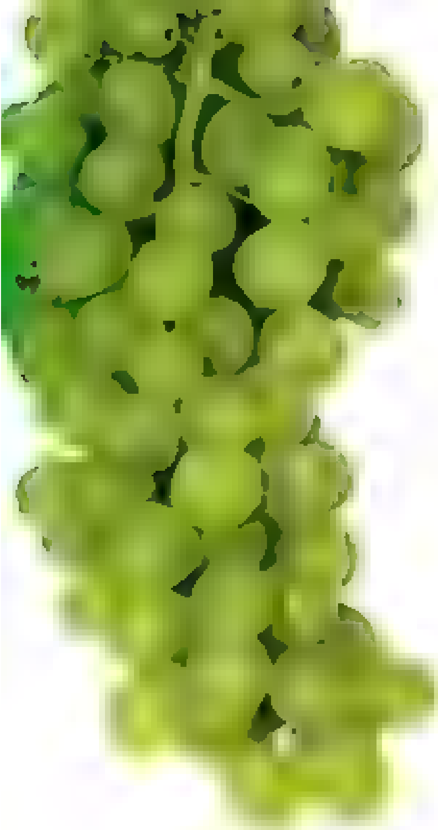
His experimental conclusions were that when the sunlight reached and penetrated the hole, it made a conic shape at the meeting point with the pinhole, and later formed another conic shape in reverse to the first one on the opposite wall in the dark room.

In later stages, these discoveries led to the invention of the camera obscura, and Ibn al-Haitham built the first camera, a camera obscura or pinhole camera, in history. He went on to explain that we see objects upright and not upside down, as the camera does, because of the connection of the optic nerve with the brain, which analyses and defines the image.

During his practical experiments, Ibn al-Haitham often used the term *al-Bayt al-Muthlim*, which was translated into Latin as *camera obscura*, or dark, private or closed room or enclosed space. Camera is still used today, as is *qamara* in Arabic which still means a private or dark room.

Many of Ibn al-Haitham's works, especially his huge *Book of Optics*, were translated into Latin by the medieval scholar Gerard of Cremona. This had a profound impact on the 13th-century big thinkers like Roger Bacon and Witelo, and even on the 15th-century works of Leonardo da Vinci.

Today, that camera has gone from the humble beginnings of Ibn al-Haitham's dark front room, the *qamara*, to become a sophisticated digital process, while the study of optics has blossomed into a whole science covering lasers, optical sectioning of the human retina and researching red bioluminescence in jelly fish.



Fine Dining

We can thank a 9th century man with the nickname 'the blackbird' for introducing the concept of three-course meals into Europe. Eating habits were totally transformed when Ziryab soared into Andalusia in the 9th century and said meals should start with soup, followed by a main course of fish, meat or fowl, and finish off with fruits and nuts.

Muslims ate according to seasonal influences. Typical winter meals used rich vegetables such as seakale, beet, cauliflower, turnips, parsnips, carrots, celery, coriander, peas, broad beans, lentils, chickpeas, olives, hard wheat, pasta and nuts. These were usually eaten with meat dishes. Desserts usually consisted of dried fruits such as figs, dates, raisins and prunes. These were accompanied by drinks made from syrups of violet, jasmine, aloes, medicament spices, fruit pastels, and gums.

In contrast, their summer diet consisted of eleven types of green beans, radishes, lettuces, chicory, aubergines, carrots, cucumbers, gherkins, watercress, marrow, courgettes and rice. The meat accompanying these vegetables was mainly poultry, ostrich and beef products.

Desserts included fruits such as lemon, lime, quinces, nectarines, mulberries, cherries, plums, apricots, grapes, pomegranates, watermelon, pears, apples and honeymelon. Meanwhile, drinks were made from syrups and preserves of fruit pastels, lemon, rose, jasmine, ginger and fennel.

This banquet of food was presented on a tablecloth, the concept of which was spread in Andalusia by Ziryab. He also changed the heavy metal drinking goblets and gold cups found on the dinner tables of the Cordoban court to delicate crystal.

In European aristocratic circles, the demand for Muslim foodstuffs and spices increased rapidly. Sources from the chronicles of the

[illegible] Cordoba, Andalusia [illegible] [illegible] read more about [illegible] chapter.

[illegible] 2005 [illegible] With [illegible] fashion, and even toothpaste.

Left: Rock crystal ewer from the Fatimid period in Cairo, Egypt dating from the 10th or 11th century. Crystal was brought to the dinner table by Ziryab in the 9th century, after Abbas ibn Firnas introduced crystal to al-Andalus

Pope in Avignon in the 14th century tell us that ships from Beirut brought jams, preserves, rice and special flour for cake-making, plus compensatory laxatives! Queen Cristina of Denmark, Sweden and Norway took care to follow the Muslim diet and imported their products and fruits. Since Denmark could only supply apples and rye, it is perhaps 'food for thought' to consider the origin of Danish pastries.

Crystal was available in Andalusia due to the ingenuity of another Muslim, 'Abbas ibn Firnas, who died in 887 CE. In his experiments, he manufactured glass from sand and stone, establishing a crystal industry based on rocks mined north of Badajos (Patlios). Most of the Andalusian rock crystal pieces that have reached us are found in European churches and monasteries, the most famous among them being a spherical bottle currently in the Asturga Cathedral, Spain. It bears vegetal patterns and a Kufic inscription, the common decorative elements on rock crystal pieces.

As well as introducing crystal that was used in drinking glasses, 'Abbas ibn Firnas was the same man who used glass in a most ingenious way to construct a planetarium, supplying it with artificial clouds, thunder and lightning. Naturally this astounded the 9th-century public.

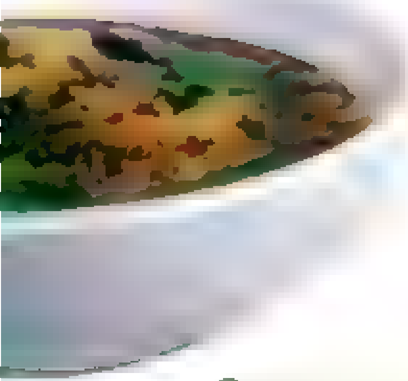
Muslim potters then introduced the art of stylish dining with a variety of ceramics and glazes. Malaga and Valencia were major centres of the industry, and Muslims revolutionized the production and decoration of pottery through their invention of lustre glaze, which you can read more about in the Market chapter and 'Pottery' section.

Both Valencian and Malagan potters exported their wares to Spanish Christian-dominated regions like southern France and as far as Italy. Here Malagan potters were thought to have laid the foundations of the famous Majolica ware, which went on to dominate the Italian ceramic industry.

Next time you have a meal, look at the ceramics and glasses. Are the plates made of fine earthenware with designs that

A 16th-century manuscript from Gelibolulu Mustafa Ali's book, *Nusret-name*, showing a banquet given by the commander-in-chief Lala Mustafa Pasha, seated at the head of the table, to the leading dignitaries of the army in Izmit. On either side of the commander are soldiers participating in the campaign, sitting according to rank. They are eating a variety of dishes with servants carrying pitchers of rosewater (their soft drink). Note the appearance of cutlery and serviettes covering the diners' laps.

look like precious metals? Are the glasses delicate, chiming if you gently tap them? We sometimes assume that just because these people lived centuries before us, they must have been worse off than us, that they must have been crude and unsophisticated; after all it was 'the dark ages' we're told, but in certain areas, their quality of life far outmeasured what we have today.



Three Course Menu

From an Anonymous Andalusian Cookbook of the 13th century
Translated by Charles Perry

Starters

Meat Soup with Cabbage

Take meat and cut it up as fine as possible. Take old cheese, the best you can obtain, and cut it up, and throw on it an onion pounded with cilantro. Take tender "eyes" of cabbage, boil, then pound them with all of that in a wooden mortar, and throw them in the pot, after boiling once or twice. Add some *murri*, a little vinegar and some pepper and caraway. Cover the contents of the pot with dough [or sourdough] and cover with eggs.

Mirkas with Fresh Cheese

Take some meat, carefully pounded as described earlier. Add fresh cheese that is not too soft lest it should fall apart, and half a piece of cut-up meat and some eggs, for it is what holds it together, along with pepper, cloves, and dry coriander. Squeeze on it some mint juice and cilantro juice. Beat it all and use it to stuff the innards, which are tied with threads in the usual way. Next, fry it with fresh oil, as aforementioned, and eat it in nibbles, without sauce, or however you like.

Main meal

Roast in a Tajine

Take an entire side of a young, plump kid and place it in a large *tajine* [earthenware cooking dish with a lid still used in North Africa today, big enough to hold it; put it in the oven and leave it there until the top is browned. Take it out, turn it and put it in the oven a second time until it is done and browned on both sides. Then take it out and sprinkle it with salt ground with pepper and cinnamon. That is extremely good and is the most notable roast that exists, because the fat and moisture stay in the bottom of the pan and nothing is lost in the fire, as in the roast on a spit or the roast in a *tannur* [clay oven].

Fish Tharid

Pound well pieces of a big fish and add to them such as they will bear of egg white, pepper, cinnamon, enough of all the spices, and a little leavening yeast. Beat them until all is well mixed. Then, take a pot and put in it a spoonful of vinegar, two of cilantro juice, one and a half of onion juice, one of *murri naqi'* [pure type of barley flour], spices, flavourings, pine nuts, six spoonfuls of oil and enough salt and water, and put it over a moderate fire. When it has boiled several times, make the pounded [fish] meat into the form of a fish and insert into its interior one or two boiled eggs, and put it carefully into the sauce while it is boiling. Cut the remainder into good meatballs, take boiled egg yolks and cloak them with that meat also. Throw all that in the pot and when all is done, take the fish from the pot and the meat-cloaked yolks, and fry them in a frying pan until browned. Then, cover the contents of the pot with six eggs, pounded almonds and breadcrumbs, and dot the pot [with yolks]

Main meal

Roast Chickens

Take young, fat chickens, clean and boil them in a pot with water, salt and spices. Take them out of the pot and pour the broth with the fat in a dish and add to it what has been said for the roast over coals. Rub that onto the boiled hen and then arrange it on a spit and turn it over a moderate fire with a continuous movement and baste it constantly, until it is ready and browned; then sprinkle it with what remains of the sauce and serve. It tastes nicer than livestock meat, and is more uniform. Other birds may be roasted the exact same way.

Sweet

Tharda of the Emir

Knead white flour well with water, a little oil and leavening yeast, making four thin *raghifs* [flatbread, rolled out decidedly thinner than a pita, like a thin pancake]. Fry them in a frying pan with much fresh oil, until they brown a little; take them out of the oil and pound them well. From the rest of the dough make little hollow things on the pattern of *mujabbana* [cheese pie], and make top crusts for them. Fry them in fresh oil, making sure they stay white and not turn brown; fry the top crusts, too. Then, take peeled pistachios, almonds, and pine-nuts, and sufficient sugar; pound them coarsely, spice them and knead them with sharp rosewater and mix with ground *raghifs* and stir until completely mixed. Fill the hollow dumplings prepared earlier with that mix, and put on their covers, and proceed confident that they will not be overdone. Arrange them on a dish and put between them the rest of the filling and then sprinkle them with sharp rosewater until the dish is full. Sprinkle with plenty of ground sugar and present it. And if some syrup of thickened, honeyed rosewater syrup is dripped on it, it will be good, God willing.

Drinks

Syrup of Pomegranates

Take a *ratl* [500g approximately] of sour pomegranates and another of sweet pomegranates, and add their juice to two *ratls* of sugar; cook all this until it reaches the consistency of a syrup, and set it aside until needed. Its benefits: it is useful in cases of fevers, cuts the thirst, alleviates bilious fevers and lightens the body gently.

Sound System

MUSIC CROSSES CONTINENTS, cultures, people and nature. Like language, it enables us to communicate, and music has run through the veins of great composers and even the tone deaf, as their favourite tunes revolve about their heads.

Islam doesn't forbid all types of music, only those which lead to improper behaviour and today the Arab world has also witnessed some great musicians like Oum Kolthoum, the late legendary songstress, also known as the 'Nightingale of the Nile,' who dominated a generation with the poetry of her songs and her lilting voice; and Muhammad Abdul Wahab, who set classical poetry from the Arab golden age alight, inspiring pride in his listeners for their rich heritage.

Do 20th-century artists and singers know that much of their craft lies in the hands of 9th-century Muslims? These artists, particularly al-Kindi, used musical notation, the system of writing music. They also named the notes of a musical scale with syllables instead of letters, called solmization. These syllables make up the basic scale in music today and we are all familiar with doh, ray, me, far, so, la, tee. The Arabic alphabet for these notes is Dal, Ra, Mim, Fa, Sad, Lam, Sin. The phonetic similarity between today's scale and the Arabic alphabet used in the 9th century is striking.

Muslims were also developing musical instruments. Eleven hundred years ago, al-Kindi suggested a detailed fretting for the *'ud* (lute) while also discussing the cosmological connotations of music. In using the alphabetical annotation for one-eighth he built on and improved the achievement of Greek musicians.

Left to right: Traditional musicians in Morocco; 18th century manuscript on musical composition and rhythm shows a *qitara* (guitar) from *Tafhim al-maqamat* by Kamani Kadir Aga

[illegible]

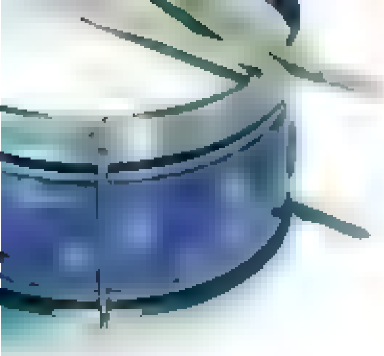
and mental condition

[illegible] musicians as depicted in Alfonso X's '*Cantigas de Santa Maria*', 13th century

About seventy years after al-Kindi, al-Farabi invented the *rabab*, an ancestor of the violin family, and *qanun*, a table zither. He wrote five books on music but *The Great Book of Music* on the theory of music was his masterpiece. In the 12th century, it was translated into Hebrew, and then into Latin. The influence of al-Farabi and his book continued up to the 16th century.

Many instruments used in traditional music, rock bands and orchestras today take their names and origins from Arabic-Muslim origins. Instruments like the lute came from the *al-'ud*, the rebec from the *rababah*, the guitar from the *qitara* and the naker from *naqqara*, a goatskin-covered wooden drum.

Roving musicians, merchants and travellers all helped Arabic music on its way into Europe, and this shaped the cultural and artistic life of Spain and Portugal under the eight hundred years of Muslim rule. One of the earliest examples of this is found in the collection of *Cantigas de Santa Maria*. Composed around 1252 upon the orders of Alfonso X el Sabio, king of Castille and Aragon, this collection consists of 415 religious songs about the Virgin Mary (pbuh).



Below right: 18th century manuscript on musical composition and rhythm showing a *rababah* from *tafhim al-maqamat* by Qumani Khadir Aga. This is an ancestor of the violin family

'Arabs, when they came to Europe, in the beginning of the eighth century, were more advanced in the cultivation of music, ... in the construction of musical instruments, than were European nations, thus only can their astounding musical influence be accounted for.'

C Engel,
a 20th century history of music scholar

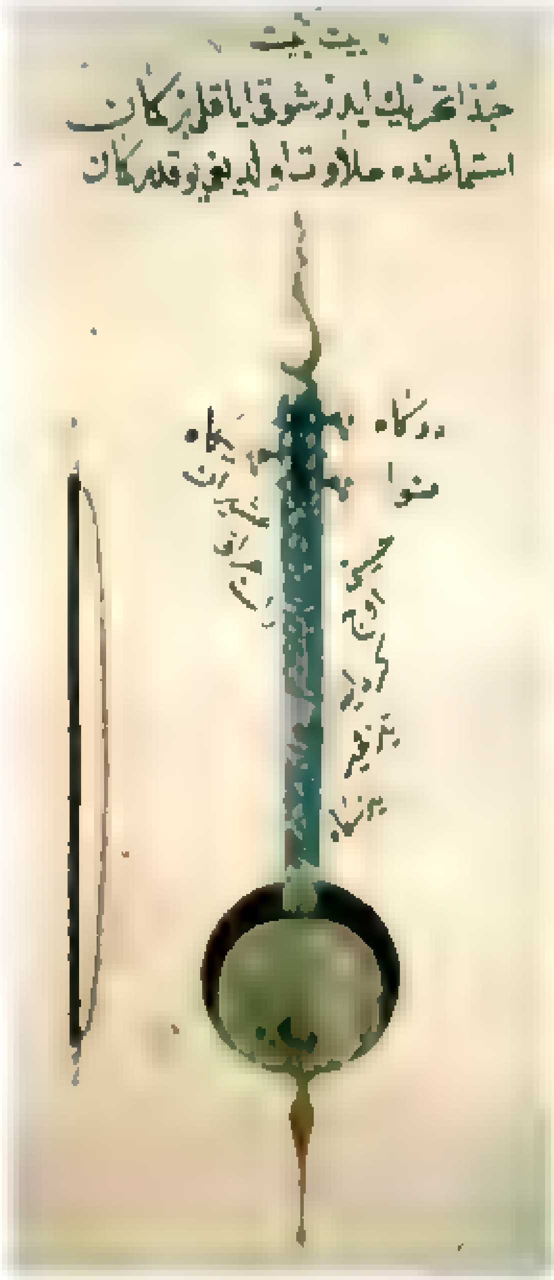
Many individuals also played a part in the spreading of music into Europe. Legendary influence lies with one man, Ziryab, known as the blackbird, because of his melodious voice and dark complexion. He was a gifted pupil of a renowned Baghdad musician but his talent and excellence in music slowly overtook his teacher's, so the Umayyad caliph invited him to Andalusia.

Ziryab settled in the court of Cordoba in 822 CE, which was then under the Caliph 'Abd al-Rahman II, the son of the Umayyad caliph. He arrived at the right time as 'Abd al-Rahman II was investing in the arts and Andalusian cultural life was flowering. Here, Ziryab found prosperity and recognition of his art, becoming the court entertainer with a monthly salary of 200 golden *dinars* in addition to many privileges. This promotion gave him a great opportunity to set his talent and creation free from any boundaries, and he went on to revolutionize music.

His accomplishments are many, including establishing the first conservatory in the world in Cordoba, teaching harmony and composition; introducing the lute (*al-'ud*) to Europe and adding the fifth bass string to it, replacing the wooden plectrum with a quill feather from a vulture; rearranging musical theory completely by setting free metrical and rhythmical parameters, so creating new ways of expression (*muwashshah, zajal* and *nawbah* suites). Many, like music historian Julian Ribera, say that counterpoint and polyphony were first developed in the Cordoba conservatory around 1000 CE.

Henry Terrace, the French 20th century historian, said, 'After the arrival of this oriental (Ziryab), a wind of pleasure and luxurious life blew through Cordoba. An atmosphere filled with poetry and exquisite delight surrounded Ziryab; he composed his songs at night in the company of two servants who played the lute. He gave his art an unprecedented value.

This unprecedented value has remained through the last millennium for the whole world to enjoy in the many different forms music takes today.



[illegible] Ottoman [illegible] was the first Euro-Asian state to have a permanent military musical band. Formed in 1299, the famous Mehterhane military band followed the [illegible] on his expeditions. It would arrive [illegible] middle [illegible] the [illegible] the soldiers while [illegible] enemy. The [illegible] had a band of six [illegible] instruments like drums [illegible] triangles, cymbals (zil) and kettledrums of war (kos and naqqara). These were [illegible] rried on the backs of camels.

Europeans met the Janissary band in peace and war. On [illegible] [illegible] [illegible] of Vienna in 1683 and [illegible] their musical instruments [illegible] an event that led to the [illegible] military bands. Even Napoleon Bonaparte's French [illegible] band [illegible] pped with Ottoman war musical instruments such as zil (cymbals) and the kettledrums. It is said that Napoleon's success in the battle of Austerlitz (1805) was due in part to the [illegible] al impact of the noise of its band.

Fashion and Style

FASHIONS MAY COME AND GO, but timeless style will always be a foundation of taste. So it may not be surprising to find out that many present European styles and ideas of dressing arrived twelve hundred years ago when Spain was part of the Islamic world.

'Beauty of style and harmony and grace and good rhythm depend on simplicity.'

Plato

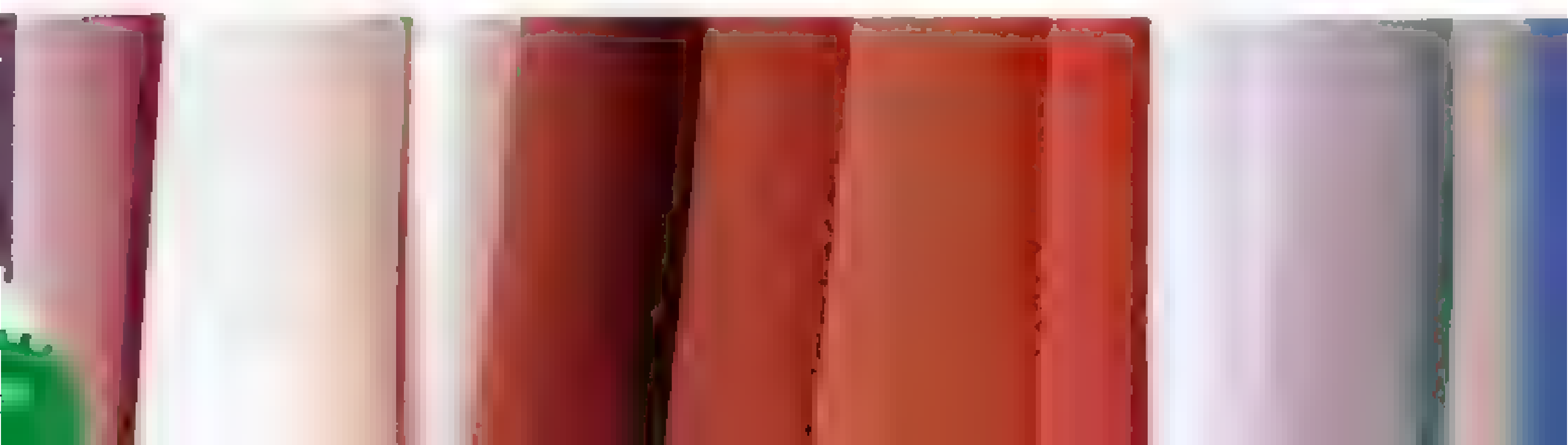
Ziryab, the musician and etiquette teacher, was also a trendsetter and style icon in 9th century Cordoba, Spain. 'He brought with him all the fashion. Baghdad was the Paris or New York of its day and … you have this influx of ideas from Baghdad to Cordoba, so he brought with him toothpaste and deodorant, and short hair.… This is the thing, Cordoba had street lighting, sewage works, running water,' said author Jason Webster about Ziryab when speaking with Rageh Omar on the BBC's recent *An Islamic History of Europe*.

Baghdad in Iraq was a great cultural and intellectual centre of the Islamic world, from which Ziryab also brought new tableware, new sartorial fashions and even the games of chess and polo. He was renowned as an eclectic man with good taste and his name was connected with elegance. With his refined and luxurious ways, he defined the court of the caliphs while the average Cordoban imitated his hairstyle, the new short look, and enjoyed the leather furniture he brought to Spain.

Henry Terrace, the French historian, said twelve hundred years later of Ziryab that, 'He introduced winter and summer dresses, setting exactly the dates when each fashion was to be worn. He also added dresses of half season for intervals between seasons. Through him, luxurious dresses of the Orient were introduced in Spain. Under his influence a fashion industry was set up, producing coloured striped fabric and coats of transparent fabric, which is still found in Morocco today.'

Ziryab's achievements gained him the respect of successive generations, even up to the present day. In the Muslim world, there is not a single country that does not have a street, a hotel, a club or a cafe named after him. In the West, scholars and musicians still pay him tribute.

His time in southern Spain coincided with a movement and development that shook the Muslim world in general, because without a doubt, a lone man could not achieve the total transformation that occurred. It's just that he,



Early 17th-century manuscript titled *Album of the Sultan Ahmed I* by Kalandar Pasha, showing typical costumes of this time

Ziryab, has become the legendary figure associated with this.

Muslims, especially in Andalusia, developed a sophisticated lifestyle pattern that was based on seasonal influences. The choice to eat particular foods and wear certain types of clothing and material was crucial in providing comfort and well being. In clothing terms, winter costumes were made essentially from warm cotton or wool items, usually in dark colours. Summer costumes were made of light materials such as cotton, silk and flax that came in light and brilliant colours from local dye works.

Andalusian Muslims were also heirs to a number of oak-based industries developed by the Romans, including the making of cork-soled shoes. They intensified and diversified the production technique and cork-soled shoes became universal in the country, and a staple of the export trade. The shoe was called *qurq*, the plural is *aqraq*, which subsequently returned to Castilian in the form *alcorque*. The artisan who made the product was a *qarraq*. Such an artisan was 'Abdullah, a Sufi mystic sandal-maker of Seville, mentioned by Ibn 'Arabi. Artisans of this trade had living quarters called *qarraqin*, now Caraquin, in Granada. Madrid also had (and still has) an oak district.

Two medieval Muslim writers, al-Saqati and Ibn 'Abdun, provide detailed specifications of the making of cork-soled shoes, notably that the leather stitched to the back should not be skimpy, and that leather should be sewn to leather, with no filler inserted in between. Some shoemakers put sand below the heel to make it higher, causing it to break when worn. The more sophisticated styles and methods were then adopted by Christians after the conquest of al-Andalus.

So the next time you're out shopping for the latest fashions in the fanciest designer shops, remember the high heels of a thousand years ago. When you try on a light pair of summer trousers or a dress remember Ziryab, the blackbird from twelve hundred years ago, because this was the time such ideas were flying into Europe from the East.

Carpets

Thankfully, about five hundred years ago carpets replaced the usual floor covering of rushes that were scattered about and changed from time to time

Fifteenth-century writer Erasmus had quite definite ideas about these rushes on English floors, saying: 'The floors are, in general, laid with white clay, and are covered with rushes, occasionally renewed, but so imperfectly, that the bottom layer is left undisturbed, sometimes for twenty years, harbouring expectoration, vomiting, the leakage of dogs and men, ale droppings, scraps of fish, and other abominations not fit to be mentioned. Whenever the weather changes a vapour is exhaled, which I consider very detrimental to health. I may add that England … would be much more salubrious if the use of rushes were abandoned.'

To avoid such pitfalls of twenty-year-old undisturbed flooring, Hampton Court is said to have had the rushes changed daily upon the orders of Cardinal Wolsey. There is also an illustration in Lambeth Palace that shows King Edward IV (1461–1483) seated in a room strewn with bright green rushes. Fortunately Cardinal Wolsey took personal interest in his floor coverings and eventually rid Hampton Court of the rushes, ordering seven carpets from Venice and another sixty Damascene carpets, originating in Damascus, in 1520.

Carpets come from an old tradition of carpet making, a tradition that started long before Islam. Carpets were first made by the Bedouin tribes of Arabia, Persia and Anatolia, who used them as tents, sheltering them from sand storms, floor coverings providing great comfort for the household, wall curtains providing privacy, and for items such as blankets, bags and saddles.

Below left: In the early 16th century, Cardinal Wolsey decided to rid the floors of Hampton Court of the unhygienic rushes and use carpet instead. He ordered sixty Damascene carpets, originating in Damascus, and a few more from Venice.

Below right: Carpets were also used to drape over camels on long journeys to add some level of comfort for the rider and also as saddle bags to store provisions.

From left to right: A Turkish lady weaving a carpet on a loom, a Muslim prostrating [illegible] prayer mat

For Muslims, carpets are held in special esteem and admired for being part of Paradise. Inspired by this, they developed both the design and weaving technique, and so their carpets came in wonderful colours. This was also due to Muslim chemistry producing new tinctures for tanning and textiles. A Tunisian scientist called Ibn Badis in the 11th century carried out pioneering work on inks and the colouring of dyes and mixtures to produce his *Staff of the Scribes*.

As well as being colourful, Muslim carpets were renowned for their quality and rich geometric patterns of stars, octagons, triangles and rosettes, all arranged around a large central medallion. Arabesque and floral patterns filled the areas around these shapes pulling it all together with a sense of unity.

Carpets could be huge, covering enormous floors of an entire audience hall, or miniature rugs for individuals which gave people a clean space to pray or simply to sit. Wherever they were, they could place the rug on the floor and know it would be clean.

In Europe carpets caught on quickly and became status symbols. King Henry VIII (ruled 1509–1547) is known to have owned over four hundred Muslim carpets, and a portrait made of him in 1537 shows him standing on a Turkish carpet with its *Ushak* star. Muslim designs also decorate his robe and curtains.

But the earliest English contact with Muslim carpets was when the grandson of William the Conqueror, who lived in the Abbey of Cluny, gave a carpet to an English church in the 12th century. At this same time, the Muslim geographer and philosopher al-Idrisi said that woollen carpets were produced in Chinchilla and Murcia, both now in Spain, and were exported all over the world.

Paintings made in the late medieval period show us how and where carpets were used and what people thought of them. In 14th and 15th century Europe, they were first used in Christian religious paintings. Then, in the 15th century, the European landed gentry displayed them from windows and balconies, like the 'Venetian Capaccio'. The 17th century saw decorative carpets covering table tops and their bases. Cupboard and window carpets also made an appearance.

Carpets were also valuable gifts, exchanged during diplomatic missions to Europe.

Belgian artists were also inspired. Van Eyck's painting of the Virgin and Child with St Donatian, St George and Canon Van der Paele, which he painted in 1436 at Bruges, shows Mary (pbuh) seated on a carpet with geometrical shapes, mainly circles, drawn arcs and rosettes combined with lozenges and eight-pointed star motifs.

Muslim carpets were so highly prized that a Victoria and Albert Museum publication quotes a chapter in Hakluyt's Voyages, entitled Certain directions given ... to M Morgan Hubblethorne, sent into Persia, 1579, talking about a plan to import Persian carpet makers into England. It says: In Persia you shall find carpets of course thrummed wool, the best of the world, and excellently coloured: those cities and towns you must repair to, and you must use means to learn all the order of the dyeing of those thrums, which are so dyed as neither rain, wine, nor yet vinegar can stain. If before you return you could procure a singular good workman in the art of Turkish carpet making, you should bring the art into the Realm and also thereby increase work to your company.

Besides the Ottoman/Turkish carpet, no other carpet reached the status and popularity of the Persian carpet, which became a state enterprise in the Safavids' reign. These rulers developed trade relations with Europe and under Shah Abbas I (1587-1629), and their export and the silk trade became the main sources of income and wealth for the Safavid state. They were also valuable gifts, exchanged during diplomatic missions to Europe.

Carpet making was a huge industry and became a professional art requiring designers to draw patterns first on paper before translating them into woven designs. This was on a massive scale, and manufacturers received orders from European consumers. Persian craftsmen from Tabriz, Kashan, Isfahan and Kerman produced eye dazzling and mesmerizing designs. Clearly knotted, ranging from medallion centred carpets, *mihrab* carpets and vase carpets to 'personalized' carpets bearing the coat of arms of a number of European rulers. Many of the carpets had a rectangular centre dominated by a medallion, and a border which could be several bands of various widths.

But by the early 19th century the carpet industry started to decline, partly due to historical events and conflicts, which lost Persia its stability and security, and because Europeans began manufacturing their own in the 18th century.

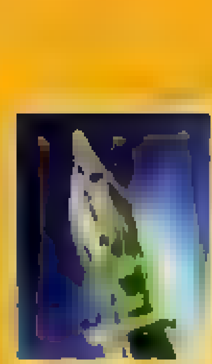
The first production of imitated Muslim carpets in Europe was under English patrons. The Royal Society of Arts promoted the establishment of successful carpet manufacturing 'on the Principle of Turkish Carpets' through subsidies and awards. So between 1757 and 1759, the Society gave £150 as awards for the best Turkish 'imitated' carpets.

Today Berber carpets, those from North Africa, are increasing in popularity faster than any other type. Berbers do not show footprint marks or vacuum tracks, and they can have thicker yarns than other level loop pile carpets. They are available to all because they come in expensive wool fibres or less expensive nylon, olefin, or nylon-olefin fibres.

With modern sophisticated manufacturing materials, carpets have become one of the cheapest available flooring methods in houses, apartments and offices. The comfort and warmth they offer has increased their popularity, making them the most used flooring system. They are also a luxury commodity, sought by collectors, textile museums and traders, while the fame of the flying carpet of Ala al-Din has added a pinch of emotional mystery. Carpeting has become essential to life in the modern world.

A Persian manuscript showing a classroom with a scholar instructing male and female students

SCHOOL



House of Wisdom

THE HEYDAY OF BAGHDAD was twelve hundred years ago when it was the thriving capital of the Islamic world. For about five hundred years the city boasted the cream of intellectuals and culture, a reputation gained during the reigns of Caliphs al-Rashid, al-Ma'mun, al-Mu'tadhid and al-Muktafi. It was the world's richest city and a centre for intellectual development, being second in size only to Constantinople, with over one million inhabitants.

People on the cutting edge of development and discovery group together and so it was in Baghdad under the four generations of these caliphs. The reason that Baghdad had reached, and maintained, such a pinnacle was that these caliphs had taken a personal interest in collecting global, groundbreaking scientific works. As well as books, they brought together Muslim scholars to create one of the greatest intellectual academies in history called the House of Wisdom. This intellectual powerhouse, coupled with the prowess of Baghdad, meant the city was the headquarters for the Arts, Sciences and Letters, and the role it played in the spread and development of knowledge in the Arts and Sciences was huge.

The House (Academy) of Wisdom was known by two names according to its development stages. When it was like a single hall in the time of Harun al-Rashid it was named *Bayt al-Hikmah* but later, as it grew into a large institute/academy, in the time of al-Ma'mun, it was named *Dar al-Hikmah*, and both mean 'the House of Wisdom'. It housed a large library, 'the Library of Wisdom' or *Khizanat al-Hikmah*, and this held a huge collection of different scientific subjects in many languages, making it a scientific academy.

Baghdad in 1932. Eleven centuries earlier this capital was the site of the House of Wisdom.

Syrian stamps issued in 1994 showing al-Kindi, a leading scholar in the House of Wisdom, who translated the work of Aristotle.

Caliph Mohammad al-Mahdi first began collecting manuscripts when he came across them during his war expeditions. His son, Caliph al-Hadi, carried on this work until his son, Caliph Harun al-Rashid, who reigned from 786 to 809 CE, formally built the scientific collection and Academy of Science. Caliph al-Ma'mun, who reigned for twenty years from 813, extended the House of Wisdom and designated a section or wing for each branch of science, so the place was full to bursting with scientists or *'Ulama*, art scholars, famous translators, authors, men of letters, poets, and professionals in the various arts and crafts.

These medieval brains met every day for translation, reading, writing, discourse, dialogue and discussion. The place was a cosmopolitan melting pot and the languages that were spoken and written included Arabic, the lingua franca, Farsi, Hebrew, Syriac, Aramaic, Greek, Latin and Sanskrit, which was used to translate the ancient Indian mathematics manuscripts.

Among the famous translators was Yuhanna ibn al-Bitriq al-Turjuman, known as 'the Translator Jonah, son of the Patriarch. He was more at home with philosophy than medicine and translated, from Latin, *The Book of Animals* by Aristotle which was in nineteen chapters. Hunayn ibn Ishaq was also a renowned translator of the books by the Greek physician Hippocrates and Galen.

Al-Kindi, the physician, philosopher, mathematician, geometer, chemist, logician and astronomer, was chosen by Caliph al-Ma'mun to be one of the scholars leading the translation of the work of Aristotle. He had his own personal library which used to be referred to as al-Kindiya.

Al-Ma'mun was a forward-thinking caliph and contacted other world leaders in his pursuit for knowledge. It is said that he wrote to the king of Sicily asking him for the entire contents of the Library of Sicily, which was rich in philosophical and scientific books. The king responded positively to the Caliph by sending him copies from the Sicilian Library.

The transportation of books varied. Without the availability of modern planes, it is also said that al-Ma'mun used a hundred camels to carry handwritten books and manuscripts from Khorasan in Iran to Baghdad.

The Byzantine emperor was also approached because al-Ma'mun wanted to send some of his scientists to translate the useful books that

were stored in his empire. The emperor said yes and the scientists went, and were also charged with bringing back any books of the Greek intellectuals.

Caliph al-Ma'mun not only steered the organization of the House of Wisdom, but also participated with the scientists and scholars in their discourses and discussions and built an astronomy centre called Marsad Falaki. It was run by his personal astronomers, a Jew named Sanad ibn Ali al-Yahoudi and a Muslim named Yahya ibn Abi Mansour. It is said that Sanad became a Muslim at the hands of al-Ma'mun himself.

As well as taking up the reins of the House of Wisdom, al-Ma'mun took after his father in establishing many higher institutes, observatories and factories for textiles. It is said that the number of higher institutes during his reign reached 332. They were packed with students pursuing various subjects in the arts and sciences.

He also apparently asked a group of wise men to prepare a map of the world for him which they did. This was known as 'al-Ma'mun's map', or *al-surah al-ma'muniyah*, which expanded upon those which were available during the lifetime of Ptolemy and other Greek geographers.

Among the House of Wisdom's luminaries of the time were the Banu Musa brothers, Muhammad, Ahmed and al-Hasan, known as mathematicians and inventors of trick devices; al-Khwarizmi, the 'father' of algebra; al-Kindi, inventor of decryption and musical theory; Saeed ibn Haroun al-Katib, a scribe or writer; Hunayn ibn Ishaq al-'Ibadi, physician and translator, and his son Ishaq. These names appear time and time again throughout this book because these individuals were researching, discovering and building a vast edifice of knowledge, based on real experiments, that has provided a firm bedrock for much of what we know today.

Al-Ma'mun was a visionary of education and some historians have given him the title of 'The Master of Arab Civilization' because of what was left behind as cultural heritage in Baghdad. The House of Wisdom and the splendour of Baghdad made it a pulsating metropolis, crowded with the great minds of the day.

However, we must distinguish between the Abbasid House of Wisdom above and the Fatimid House of Wisdom (*Dar Al-Hikma*), which was established in Cairo in 1005 by the Caliph Al-Hakim. This academy lasted 165 years. Other cities in the Eastern provinces of the Islamic world established several 'Houses of Science' (*Dar al-Ilm*), or more accurately 'Houses of Knowledge', in the 9th and 10th centuries to emulate that of *Dar Hikma* in Baghdad.

Artist's impression of the House of Wisdom in Baghdad

Schools

SPENDING UP TO SIXTEEN FORMATIVE YEARS IN SCHOOLS, we have favourite teachers, hated subjects, and a bag full of memories from sports days to sitting exams. Our lives are moulded by timetables of classes, until finally we emerge with a head full of some kind of knowledge.

In Muslim countries a thousand years ago, the school was the mosque. There was little distinction between religion and knowledge as the mosque was both the place of prayer and the place of learning. Subjects included science, so religion and science sat side by side comfortably, which was not the case in other parts of the world. According to Danish historian Johannes Pedersen [illegible] was intimately bound up with religion ... to devote oneself to both afforded [illegible] inner satisfaction and ... service to God [illegible] it not only made men of letters willing to accept deprivation [illegible] it prompted others to lend them aid.

Prophet Mohammad (pbuh) made the mosque the main place of learning, travelling between them, teaching and supervising schooling. Anywhere a mosque was established, basic instruction began. He also sent teachers of the Quran to the tribes and they were called *Ahl al-'ilm* or 'the people with knowledge.' This meant that education spread everywhere and these travelling teachers lived lives of great contentment. In Palermo, Ibn Hawqal, a 10th century geographer, merchant and traveller claimed to have counted about three hundred elementary teachers.

Stand up for your teacher and honour him with praise. For the teacher is almost a prophet. Did you see greater or more honourable than that who creates, fosters and develops personalities and brains?'

[illegible]

At the time of Prophet Mohammad (pbuh) in the 7th century there were nine mosques in Medina, which is now in Saudi Arabia. The first school then appeared here in 653 CE and the idea of schooling spread like wildfire, so one sprang up in Damascus, Syria in 744. Eighth-century Cordoba, Spain, had schools and by the late 9th century nearly every mosque had an elementary school for the education of both boys and girls.

At the age of six nearly all boys, except the rich (who had private tutors), some girls and some slave children, began elementary school. Tuition was normally free or so inexpensive that it was accessible to all. One of the first lessons in writing was to learn how to write the ninety-nine most beautiful names of God and simple verses from the Quran. After this, the Quran was studied thoroughly and arithmetic was added.

By the 10th century, teaching was moving away from the mosque and into the teacher's house, which meant that gradually schools developed, in Persia first. Then by 1066, when the Normans were invading England, the Seljuks built the Nizamiyah school, named after its founder Vizier Nizam al-Mulk of Baghdad. This was the first proper school that had a separate teaching building. However, schools (*madrasas*) were established and salaries were designated for teachers in the early days of Islam.

Like many Muslim buildings, schools were constructed with no expense spared, and beauty was an important consideration. Each had a courtyard with one, two, three or four *Iwans* (large arched halls directly open to the courtyard), which were used for lessons, as well as a prayer hall, living accommodation (individual rooms) and an ablution complex. For the first time,

Left: Two schools in Baghdad in 1890. Right: Bayazid II Kulliye, a university complex consisting of mosque, *madrasa* and hospital in Edirne, Turkey.

the state or ruling caliph exercised some supervision over teaching, and teachers had to have permission before they could teach.

A 14th-century Muslim educationalist Ibn al-Hajj had much to say about schools: "The schools should be in the bazaar or a busy street, not in a secluded place.... It is a place for teaching, not an eating house, so the boys should not bring food or money.... In the organization, a teacher must have a deputy to set the class in their places, also visitors according to their rank, to awaken the sleepers, to warn those who do what they ought not or omit what they ought to do, and bid them listen to the instruction. In class, conversation, laughing and jokes are forbidden."

By the 15th century, the Ottomans had revolutionized schools by setting up learning complexes in towns like Bursa and Edirne in Turkey. Their school system was called *Kulliye*, and constituted a campus-like education, with a mosque, hospital, school, public kitchen and dining area. These made learning accessible to a wider public while also offering free meals, health care and sometimes accommodation. The Fatih Kulliye in Istanbul was such a complex, with sixteen schools teaching science and theology.

Where did all the money come from for all these institutions? Well, not so much in taxes, but from public funds that were charitable donations from a foundation called *waqf*. Anyone could set up a school under a deed of foundation as long as they abided by the beliefs of Islam. Finance covered maintenance, teachers' salaries, accommodation, food for students, and also bursaries for those in need.

Because education was held in such high esteem, money was given generously and learning flourished. Ibn Battuta, the 14th century Muslim globetrotter, talks about the student, who was supported one hundred per cent: "... any one who wishes to pursue a course of studies or to devote himself to the religious life receives every aid to the execution of this purpose."

Many students in the 21st century would like such free education, and even though the 14th century may seem like a long time ago, the methods of organization, logistics and system of institutionalization could maybe offer a few pointers for today.

Turkish miniature from the 17th century by Mehmed Ashik shah, showing the Ghazanfar Aga madrasa in Istanbul.

Universities

TODAY, more people than ever before are applying for university education. In the UK alone, just less than half a million people want to start studying full time courses, and more women than men are continuing on the path of learning. This quest for knowledge was also close to the heart of Muslims as they are urged throughout the Quran to seek knowledge, observe and reflect. This meant that all over the Muslim world, advanced subjects were taught in mosques, schools, hospitals, observatories and the homes of scholars.

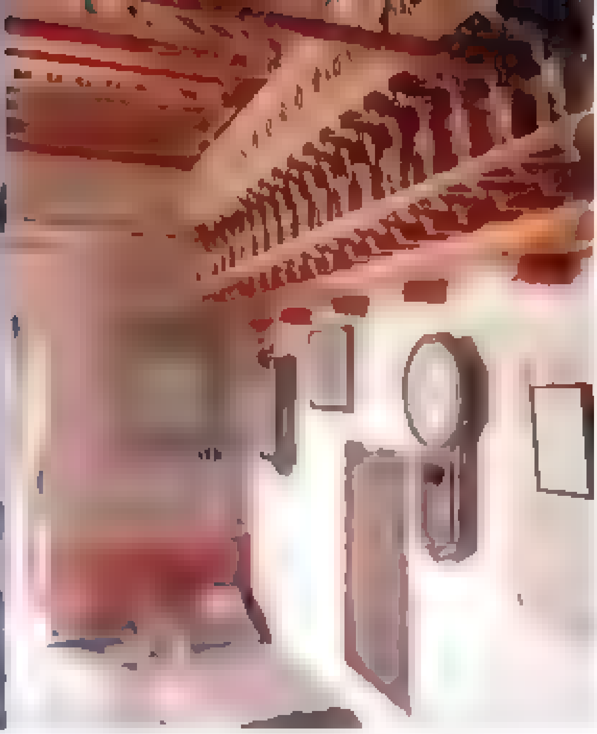
'Seek knowledge from the cradle to the grave.'

You'll have read about school education in this chapter, and know that once 'primary' education was complete, a student could go on to further study in Arabic grammar and poetry, logic, algebra, biology, history, law and theology. There were also scientific academies which had their own rectors.

There is some overlap between school and university education. Both began in the mosque, but 'University' in Arabic is *jami'ah*, which is the feminine form of the Arabic for mosque, *jami'*. So in Arabic the place of religion and the place of advanced learning are completely tied together. There is no equivalent in other cultures or languages, and some of the mosques of Islam are the oldest universities.

Famous mosque universities include al-Azhar which is still running today, one thousand and thirty years later. Being the focal point of higher learning in Egypt, it attracted the cream of intellects. So it is known for its age, and also for its illustrious alumni. Ibn al-Haytham, who discovered how we see, lived there for a long time and Ibn Khaldun, a 14th century leading sociologist, taught there.

The al-Azhar mosque University in Cairo, founded in 972, remains one of the renowned traditional universities of Islam today.



Left: Courtyard of al-Qarawiyin showing a *Anaza* behind the fountain normally used for prayer on summer evenings.

Right: The timing room at al-Qarawiyin housing a fully functioning water clock showing a series of brass jars, and an astrolabe indicating days and months. On the white wall hangs one of the oldest European [illegible] clocks. On the floor is [illegible] bed on which the time keeper sleeps. Outside this room there is a sundial (not shown).

A grand college mosque complex was al-Qarawiyin in Fez, Morocco. This university was originally built as a mosque during the Idrisids' Rule in 841 CE by Fatima al-Fihri, a devout and pious young woman. She was well educated, and after inheriting a large amount from her father, who was a successful businessman, vowed to spend her entire inheritance on building a mosque/university suitable for her community in Fez. She put a design constraint on the building that all the building material should be from the same land. On launching the project she began a daily fast until the campus building was completed.

Fatima al-Fihri wanted to give the Fez community a learning centre. Like some of the grand mosques, al-Qarawiyin soon developed into a place for religious instruction and political discussion, gradually extending its education to all subjects, particularly the natural sciences, and so it earned its name as one of the first universities in history.

The university was well equipped, especially with astronomy instruments, and the 'timers room' had astrolabes, sand clocks and other instruments to calculate time.

As well as astronomy, studies were in the Quran and theology, law, rhetoric, prose and verse writing, logic, arithmetic, geography and medicine. There were also courses on grammar, Muslim history, and elements of chemistry and mathematics. This variety of topics and the high quality of its teaching drew scholars and students from all over.

So overwhelming was the number of applicants that the university had to introduce a rigorous selection system, just like universities today. Back then, the conditions included learning the whole Quran and good knowledge of Arabic and general sciences.

These mosque 'universities' not only took local students, they were international affairs. So in the famous Abbasid universities of Baghdad, Iraq, medicine, pharmacology, engineering, astronomy and other subjects were taught to students from Syria, Persia and India. Students at al-Azhar University in Cairo included large numbers of foreigners, alongside Egyptians from areas outside Cairo. They were all given residential units that they had to look after and received free food. Every large unit also included a library, kitchen and toilet.

This 'university' [al-Qarawiyin in Fez] was number one in Morocco, built in 841 CE by Fatima al-Fihri.... [who] wanted to give... [her] community a learning centre.

Ibn Sina, also known as Avicenna, [illegible] surrounded by students from a [illegible] century Persian manuscript

Financial support for students was part of the educational package. At the al-Qarawiyyin Mosque university in Morocco students didn't pay fees, unlike students of today, and were given monetary allowances for food and accommodation. All this was made possible by endowments from royal families. Students lived in residential quadrangles, in two- and three-storey buildings, each with between sixty and one hundred and fifty other students.

Like all good universities, these also had phenomenal libraries with a lot of books given

Graduation ceremonies could have started in Cordoba.

from personal collections. At the Zaytuna Mosque in Tunisia, there were manuscripts on grammar, logic, documentation, etiquette of research, cosmology, arithmetic, geometry, minerals and vocational training. At the Tunisian Qayrawan's Atiqa Library, there was an Arabic translation of *History of Ancient Nations* which was written by St Jerome before 420 CE.

The teaching was in a study group, known as a *halaqat al-'ilm* or *halaqa*. This was a semi circle in front of the teacher formed by seated students. Visiting scholars were allowed to sit beside the lecturer as a mark of respect, and in many *halaqas* a special section was always reserved for visitors. The Mosque of Amr near Cairo had more than forty *halaqas* at some point, and in the chief mosque of Cairo there were 120 *halaqas*.

Courses were difficult, and medicine was particularly gruelling, like in universities today, with the department of medicine having a hard and long examination. Anything less than a pass meant that person couldn't practice medicine and was formally pronounced incompetent.

The students of law went through undergraduate training and, if they were successful, were chosen by their master as a fellow. Only then could they go onto graduate studies which lasted an indefinite period of time. It could be up to twenty years before they acquired their own professorial chair. The law student had to get a certificate of authorization and a license before practising.

These certificates, known as *ijazas*, could be the origin of the word 'baccalareus' which is the lowest university degree. The term first appeared in the University of Paris degree system set up in 1231 by Pope Gregory IX. It could be a latinized Arabic phrase that the Muslims used. *Bi-haqq al-riwayah* meant 'the right to teach on the authority of another', and this phrase was used in the 'degree certificates', *ijazas*, for six centuries. When a student graduated he was given this license and it literally meant he now had 'the right to teach.'

Now the International Baccalaureate is a qualification for international students getting them ready for universities anywhere in the world.

Muslims institutionalized higher level education. There were entrance exams, challenging finals, degree certificates, study circles, international students and grants. In fact, there is a remarkable correspondence between the teaching procedures in medieval universities' and the methods of the present day. They even had collegiate courses, prizes for proficiency in scholarship, and oratorical and poetical competitions.

'Books were presented and many a scholar bequeathed his library to the mosque of his city to ensure its preservation and to render the books accessible to the learned who frequented it. And so grew up the great universities of Cordoba and Toledo to which flocked Christians as well as Moslems from all over the world.'

J. S. Mackensen, a contemporary European historian of Islamic librarianship

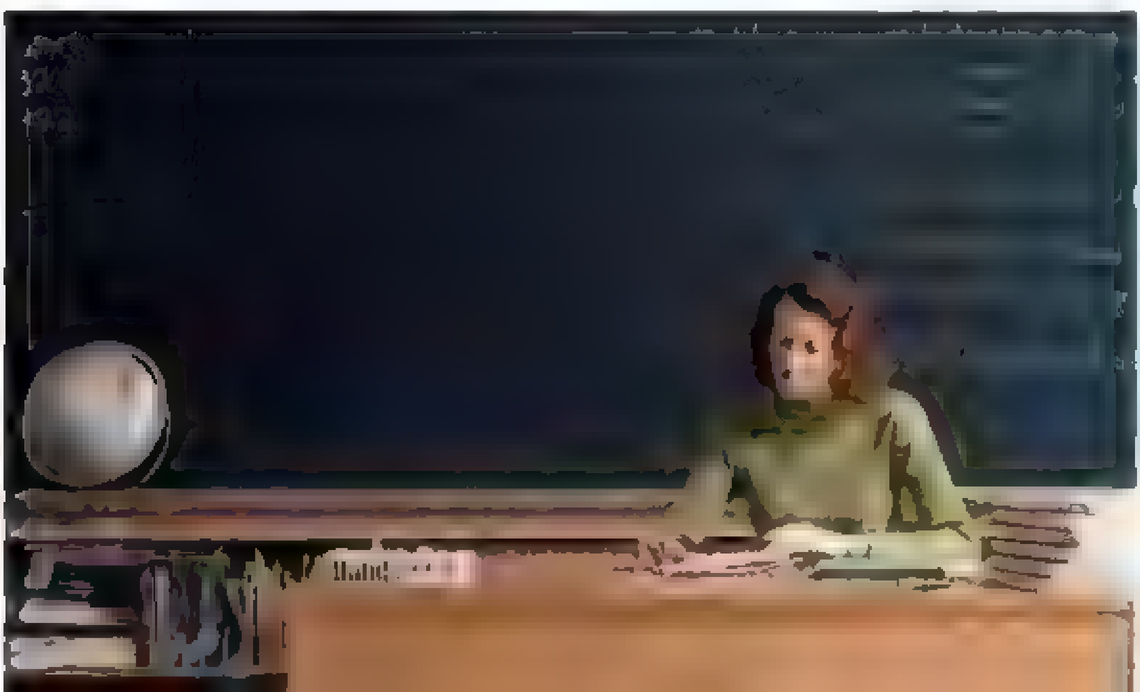
The Professor's Chair

YOU MUST HAVE WONDERED WHY A CHAIRMAN OR WOMAN, a professional head of an organization, is called by such a title. In today's terminology they are often just referred to as the 'chair'. This usually means a professor who has been awarded the chair of, say, mathematics, or it is a president who presides at the meetings of an organization and people have to address their remarks to this 'chair' person.

Well, if we go back to the teaching in the mosques, Muslim schools and universities over a thousand years ago, we'll find a study circle or a *Halaqat al-'ilm* or *halaqa* gathered around a professor who was seated on a chair or *kursi* in Arabic. Initially, it was just to give the teacher a comfortable place and to make him higher than the seated students so they could see and hear him better. It is this notion of 'chair', or *kursi*, that evolved into a professional position, like the chair of a board or a committee.

The professor in the chair of the study circles was either chosen by the caliph or by a committee of scholars (*al-Hawza*), as in present-day Qum in Iran or Najaf in Iraq. They are chosen for their scholarly prowess and popularity. Ibn 'Aqil, a scholar who died in 1119, was appointed to a well known chair in *Jami' al-Mansur* in Baghdad, and he became the main teacher. Outstanding, distinguished and popular scholars could be appointed to two chairs at the same time, and they would lecture at two mosques.

Some chairs were also known by the discipline they represented, so there was chair for the study circle of the traditionalists or *halaqat ahl al-hadith*, and one for the grammarians,



halaqat al nahwiyin. Others were known by the name of the family whose members occupied it in succession, so there was the chair of the Barmakids or *halaqat al Baramikah*. Sometimes institutions specialized in particular fields and therefore received a corresponding chair, like the Nizamiyah, a school in Khargird, Iran, which did not have a chair of theology, but only a chair of law.

Once a professor was appointed by the caliph to a chair in one of the main mosques or *Jami*, he ordinarily held it for the remainder of his lifetime. Cases of lengthy tenure are frequent, like Abu 'Ali al Kattani, who was in his eighties when he died in 1061 after occupying his chair for fifty years.

Sometimes professors moved from one main mosque to another like, Sharif Abu Ja'far, who died in 1077. He first held a chair in *Jami' al Mansur*, on the west side of Baghdad. Then he moved to the east side, where he taught in an exclusive institution near the Caliphal Palace, before moving further north once again, because of a flood in 1074, when he was appointed a new chair in *Jami' al Qasr*.

At times when the chair or chairs were vacated by the death of the incumbent, another was selected, usually based on his seniority and competence.

So next time you are in a meeting, you now know where the peculiar term 'chair' originated from and why.

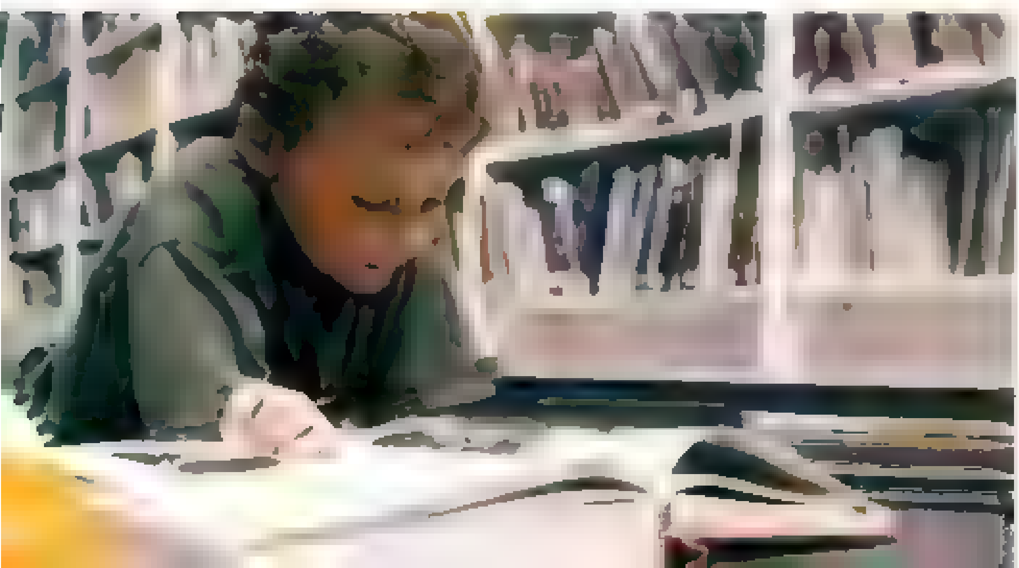
13th century illustration of a sermon in a mosque from the *Maqamat* or *Assemblies* of al Hariri. Note that the only person on the chair (*minbar*) is the lecturer, and this is where the term chair (as in university chair) comes from

Libraries

WITH THE APPEARANCE OF THE TELEVISION it was predicted that the shelf life of books faced certain doom but books have held their own. The introduction of the internet was the next big challenge but books still continue to enthral both young and old. Books have weathered the coming of modern entertainment technology as academic treatises, magic books, adventures, thrillers, romantic stories and biographies. Today, as a thousand years ago, they still captivate, inspire and draw people into their silent personal world, and there is nowhere that this world exists more than in the corridors and bookcases of libraries.

"... there can be no education without books."

Books, manuscripts and treatises covering every area of Muslim science, technology and arts were produced in astronomical proportions. Right from the 8th century Muslims began producing books, because they knew how to make paper, and because they were greatly encouraged to record all their experiments. The Abbasid Caliph al-Ma'mun paid translators the weight of each book in gold that they translated from Greek into Arabic. This produced a vast stack of books, commanding the attention and respect of following generations, Muslim and non-Muslim. During the Abbasids, hundreds of libraries (also privately owned) were opened, making many thousands of books available to readers.



Before the science books came the very first book in Islam in the 7th century. This was the Quran, which was revealed to Prophet Mohammed (pbuh) in the form of messages called *Aayats* or verses. These were immediately memorized by several companions and written down by scribes on whatever material was available like leaves, cloth, bones and stones. The earliest full copy of the book was kept by Hafsah, the daughter of the second caliph, Omar. The arrangements of the verses were in chapters or *Suras* and the location of each chapter was personally checked and revised by the Prophet (pbuh) himself. Several copies existed, but most of these contained personal explanatory notes by their owners.

All these copies needed to be collected to produce a single standard copy without additional comments, and that was also checked against the original version of Hafsah. This copy of the Quran was produced by 'Uthman ibn 'Affan, the third caliph, which led to standardization of reading and writing styles and made it easier to spread. Copies of this fourteen-hundred-year-old Uthman manuscript are still available in major libraries of the world, and the present copy of the Quran is an authentic duplication of this original 7th-century manuscript.

Aleppo in Syria probably had the largest and oldest mosque library, called 'the Sayfiya', at the city's grand Umayyad Mosque, with a collection of ten thousand volumes. These were reportedly bequeathed by the city's most famous ruler, Prince Sayf al-Dawla.

The Sayfiya was the oldest and largest, but the library at the Zaytuna Mosque college complex in Tunis was possibly the richest of all. It had tens of thousands of books and it is said that most rulers of the Hafsid dynasty competed with each other for the prestige associated with maintaining and strengthening this library. So at one point, the collection exceeded a hundred thousand volumes.

Developing strong attachments to books meant Muslims also loved book collecting and establishing libraries. There were public and private libraries, with a huge network of public libraries in mosques in most big cities, plus prestigious private collections which attracted scholars from all parts of the Muslim world. The books or manuscripts in them were about the size of the modern book, containing good quality paper with writing on both sides, and bound in leather covers.

Public book collections were so widespread that it was impossible to find a mosque, the learning institution, without a collection of books. Before the Mongols decimated Baghdad in 1258, it had thirty-six libraries and over a hundred book dealers, some of whom were also publishers, employing a corps of copyists. There were similar libraries in Cairo, Aleppo and the major cities of Iran, Central Asia and Mesopotamia.

Mosque libraries were called *dar al-kutub*, or 'The House of Books', and they were the focus of intellectual activity. Here writers and scholars dictated the results of their studies to mixed audiences of young people, other scholars and interested laymen. Anyone and everyone could take part in the discussions. Professional *warraqs* or scribes then copied and turned them into books. Even when the books were especially commissioned, they would still be published in this way.

A view of the New York Public Library

'The book is silent as long as you need silence, eloquent whenever you want discourse. He never interrupts you if you are engaged, but if you feel lonely he will be a good companion. He is a friend who never deceives or flatters you, and he is a companion who does not grow tired of you.'

Al-Jahiz, Muslim philosopher and man of literature, 8th century

It wasn't just public libraries that were huge, as individuals had immense libraries too. Edward Gibbon, a historian, tells a story of a private Muslim doctor who refused an invitation from the Sultan of Bukhara to visit because to take his books would have required four hundred camels, and he wasn't leaving without them!

Al-Jahiz, an 8th-century Muslim philosopher and man of literature, returned to his home in Basra after spending more than fifty years in Baghdad, studying and writing about two hundred books. These included a seven-volume *Book of Animals*, which had observations on the social organization of ants, communication between animals and the effects of diet and environment. Other books were *The Art of Keeping One's Mouth Shut* and *Against Civil Servants*. He died an appropriate death in his private library in 868, at the age of ninety-two, when a pile of books fell on him.

These people loved books so much that when they died it was a tradition to donate their collected manuscripts, sometimes thousands of volumes, to the mosque libraries, for all to enjoy. The historian al-Jaburi says that Nayla Khatun, a wealthy widow of Turkish origin, founded a mosque in memory of her deceased husband, Murad Efandi, and attached a school and a library to it. Other books came from travelling scholars as they showed their gratitude to mosques for giving them free accommodation, food and stationery.

Libraries could be grand affairs. In Shiraz, Iran, these 10th-century complexes were described by the medieval historian, al-Muqaddasi, as

buildings surrounded by gardens with lakes and waterways ... topped with domes, and comprised an upper and a lower story with a total ... of 360 rooms ... In each department, catalogues were placed on a shelf ... the rooms were furnished with carpets.

Some libraries, like those of Shiraz, Cordoba and Cairo, were in buildings separate from the mosque. They were spacious, with many rooms for different uses: shelved galleries to store books; reading rooms; rooms for making copies of manuscripts; and rooms for literary assemblies. All these were adequately lit and comfortable, with carpets, mats and seating mattresses.

Like libraries today, those of a thousand years ago were highly ordered, with both public and private libraries having book classification systems, and accurate cataloguing to help readers. It also gave librarians control over the quality and quantity of their resources.

In 1050, the book collection of al-Azhar library in Cairo had more than a hundred and twenty thousand volumes recorded in a sixty-volume catalogue totalling about three thousand five hundred pages. In Spain, the catalogue for the works in al-Hakam's library was alleged to have consisted of forty-four volumes.

The Public Library of Hulwan in Baghdad, from a 13th-century manuscript of the *Maqamat or Assemblies* of al-Hariri

Just as there was a cataloguing system, the books were arranged to make it easy to find them. So books could be in separate cases or even in separate rooms in the Baghdad libraries, and the content of each section of a bookshelf was written on a strip of paper attached to the outside of the shelf. This told the reader which works were incomplete or lacking in some part.

People can borrow books from libraries today, and it was the same a thousand years ago. The Muslim medieval historian, Yaqut, said that he could take out two hundred volumes on loan without leaving a pledge. That's a lot of reading and maybe he was a rare case, but it does highlight the desire that people had to read and have access to books. Most book lending, though, had rules and regulations, like today. Readers were urged to take great care of borrowed books, and not to write comments or correct any mistakes found in the book, but instead to report them to the librarian. They also had to return the borrowed items by a given date.

Librarians were also appointed to take charge and this was an honoured position, only for the most learned. Only those 'of unusual attainment' were considered as custodians of the libraries, the guardians and protectors of knowledge. The management of the libraries of the Almohad dynasty, the rulers in North Africa in the 12th and 13th centuries, was one of the most privileged state positions.

All these libraries were the holders of vital knowledge and as Ralph Waldo Emerson, a 19th-century American writer said: 'Consider what you have in the smallest chosen library. A company of the wisest and wittiest men that could be picked out of all civil countries, in a thousand years, have set in best order the results of their learning and wisdom ... [it] is here written out in transparent words to us, the strangers of another age.'

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Mathematics

THERE ARE QUITE A FEW MATHEMATICAL IDEAS that were previously thought to have been brilliant conceptions of 16th, 17th and 18th century Europeans. From the studying and unearthing of manuscripts we now know that Muslim mathematicians, about four hundred years earlier, were calculating with great intensity. Many of these mathematicians came from the Iran/Iraq region around 800 CE, when the House of Wisdom was the leading intellectual academy in Baghdad. You can read more about the House of Wisdom in a section in this chapter.

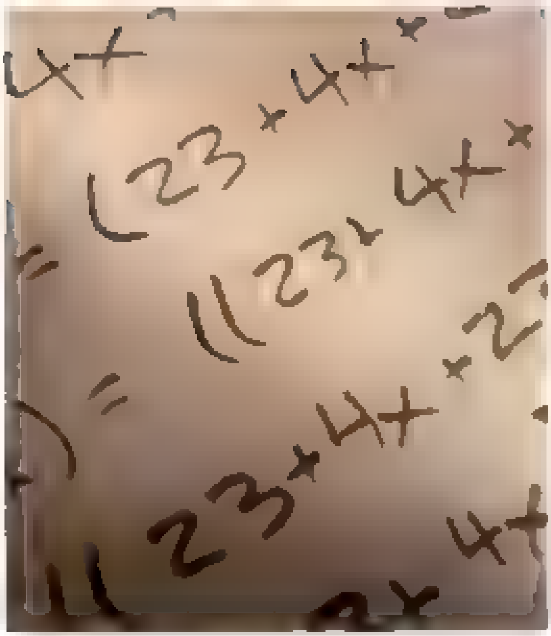
This remarkable period in the history of mathematics began with al-Khwarizmi's work, when he introduced the beginnings of algebra. It's important to understand just how significant this new idea was. In fact, it was a revolutionary move away from the Greek concept of mathematics, which was essentially based on geometry.

Algebra was a unifying theory that allowed rational numbers, irrational numbers and geometrical magnitudes to all be treated as 'algebraic objects'. It gave mathematics a whole new dimension and a development path, much broader in concept than before. It also enabled future development. Another important aspect of the introduction of algebraic ideas was that it allowed mathematics to be applied to itself in a way that was not possible earlier.

The torch of algebra was taken up by the successor of al-Khwarizmi, a man called al-Karaji, born in 953 CE. He is seen by many as the first person to completely free algebra from geometrical operations, and to replace them with the arithmetical type of operations which are at the core of algebra today. He was first to define the monomials $x, x^2, x^3, \ldots$ and $1/x, 1/x^2, 1/x^3, \ldots$ and to give rules for products of any two of these. He started a school of algebra which flourished for several hundreds of years.

Two hundred years later, a 12th century scholar al-Samawal was an important member of al-Karaji's school. He was the first to give algebra the precise description of '... operating on unknowns using all the arithmetical tools, in the same way as the arithmetician operates on the known.'

Al-Khwarizmi, the father of algebra, on a commemorative stamp issued in 1983 by the former Soviet Union



The next contribution to the algebraic story was with Omar Khayyam, known today as the poet Umar al-Khayyam, who was born in 1048. He gave a complete classification of cubic equations, with geometric solutions found by means of intersecting conic sections. He hoped to give a full description of the algebraic solution of cubic equations and said: 'If the opportunity arises and I can succeed, I shall give all these fourteen forms with all their branches and cases, and how to distinguish whatever is possible or impossible so that a paper, containing elements which are greatly useful in this art will be prepared.'

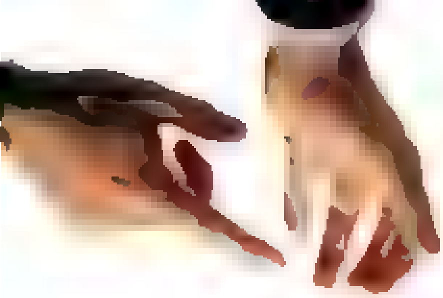
In the mid-12th century, while al-Samawal was studying in al-Karaji's school, Sharaf al-Din al-Tusi was following Khayyam's application of algebra to geometry. He wrote a treatise on cubic equations, and in it said that algebra '... represents an essential contribution to another field, which aimed to study curves by means of equations,' thus inaugurating the field of algebraic geometry.

Algebra is only one area where Muslim mathematicians significantly changed the course of its development. Back in 9th-century Baghdad and in the House of Wisdom were a group of three brothers called the Banu Musa brothers. You can read more about them in the Home chapter and how they developed their trick devices. They were gifted mathematicians, and one of their students was Thabit ibn Qurra, who was born in 836. He's probably best known for his contribution to number theory, where he discovered a beautiful theorem allowing pairs of amicable numbers to be found. This term refers to two numbers such that each is the sum of the proper divisors of the other.

Amicable numbers played a large role in Arabic mathematics, and in the 13th-century al-Farisi gave new proof of Thabit's theorem, introducing important ideas concerning factorization and combinatorial methods. He also gave the pair of amicable numbers 17,296 and 18,416, which have been attributed to Euler, an 18th-century Swiss mathematician. And many more years before Euler, another Muslim mathematician, Muhammed Baqir Yazdi, in the 17th century, gave the pair of amicable numbers 9,363,584 and 9,437,056.

Muslim mathematicians excelled, in the 10th century, in yet another area when Ibn al-Haitham was the first to attempt to classify all even perfect numbers (numbers equal to the sum of their proper divisors), such as those of the form $2^{k-1}(2^k-1)$ where 2^k-1 is prime. He was also the first person that we know to state Wilson's theorem, namely that if p is prime then $1+(p-1)!$ is divisible by p, but it's unclear whether he knew how to prove this result. It is called Wilson's theorem because its 'discovery' is attributed to John Wilson, a Cambridge mathematician in 1770, but again we don't know whether he could prove it or whether it was just a guess. It was a year later when a mathematician called Lagrange gave the first proof, seven hundred and fifty years after its 'first discovery'.

... al-Khwarizmi's work ... introduced the beginnings of algebra. It's important to understand just how significant this ... was.



In the 10^{th} century, the Muslim business community relied on finger counting and initially were not keen on using Arabic numerals. They eventually came around to the idea and it is these same Arabic numerals that are used in international business circles today, now known as English numbers.

'Mathematics is the door and key of the sciences and things of this world.. It is evident that if we want to come to certitude without doubt and to truth without error, we must place the foundations of knowledge in mathematics.'

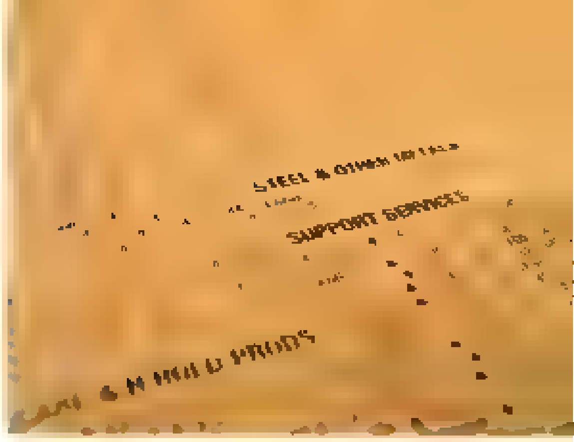
Roger Bacon

Mathematics was also needed in business and everyday use, and in particular counting systems were essential. Today most of us are only aware of one counting system which begins with zero and carries on into the billions and trillions, but back in 10^{th}-century Muslim countries there were three different types of arithmetic used, and by the end of the century, authors such as al-Baghdadi were writing texts comparing them. These three systems were finger-reckoning arithmetic, the sexagesimal system and the Arabic numeral system.

Finger-reckoning arithmetic came from counting on fingers with the numerals written entirely in words and this was used by the business community. Mathematicians such as Abu al-Wafa' in Baghdad in the 10^{th}-century wrote several treatises using this system. He was actually an expert in the use of Arabic numerals but said these '... did not find application in business circles and among the population of the Eastern Caliphate for a long time.'

The sexagesimal system had numerals denoted by letters of the Arabic alphabet. It came originally from the Babylonians, and was most frequently used by the Arabic mathematicians in astronomical work.

The arithmetic of the Arabic numerals and fractions with the decimal place-value system was developed from an Indian version. The Muslims adapted the Indian numerals into the modern numbers, 1 to 9, we have today, which are called Arabic numerals, believed to have been based on the number of angles each character carries, but number 7 creates a challenge as the medial cross line is a recent 19^{th} century development. These have become the numerals we use in Europe and North Africa today, as distinct from the Indian numerals that are still used in some eastern parts of the Muslim world. Number 1, for example, had one angle, 2 has two angles, 3 has three and so on. The arrival of these numerals

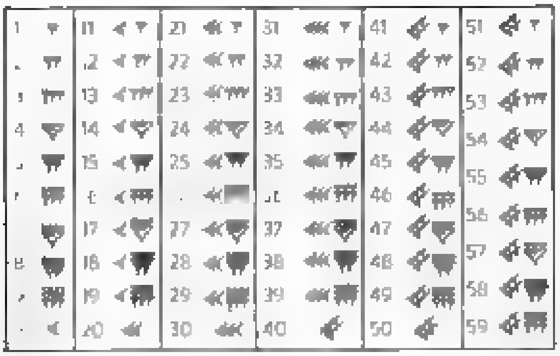


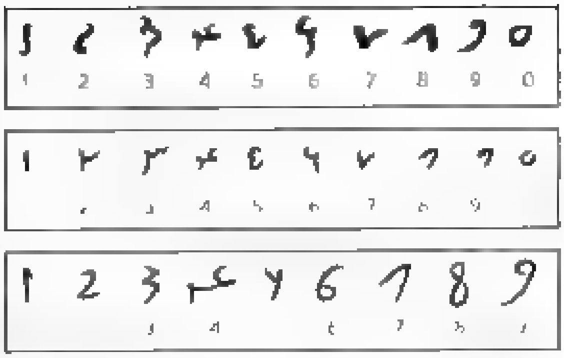
resolved the problems faced by the then used Latin numerals. The Arabic numerals were referred to as the *ghubari* numerals because the Muslims used dust (*ghubar*) boards when making calculations instead of an abacus.

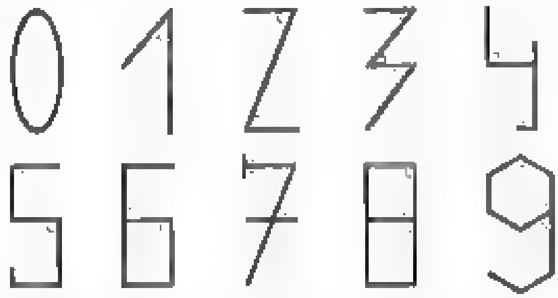
A great refinement by Muslim mathematicians of the Indian system was the wider definition and application of the zero. Muslims gave it a mathematical property, such that zero multiplied by a number equals zero. Previously zero defined a space or a 'nothing'. They also used it for decimalization, hence making it possible to know whether, for example, the writing down of 23 meant 230, 23 or 2300. It's interesting to note that if we imagined the zero sitting inside a hexagon, the ratio of the diameter of the circle to the side of the hexagon would equal the golden ratio. To read more about the golden ratio see the 'Geometry' section in this chapter.

Muslim scholars were also fascinated by the significance of some numbers, such as the link of 0 and 1 to the one of the 99 attributes of God, 'nothing before Him and nothing after Him.' It is interesting to see how 0 and 1 are the only two digits used in all computers of today.

Arabic numerals came into Europe by three sources: Gerbert (Pope Sylvester II) in the late 10^{th} century, who studied in Cordoba and then returned to Rome; Robert of Chester in the 12^{th} century, who translated the second book of al-Khwarizmi's (which contained the second *ghubari* Arabic numerals). This route of Arabic numerals into Europe is mentioned by contemporary historian Karl Menninger in *Number*







From left to right: The babylonian sexagesimal number system with the example figure of 424,000; the progression of Arabic numerals from the 10th to the 14th centuries, showing how the Muslims devised modern numerals, numbers 1 to 9, that we use today in English, based on the use of angles. Number 1, for example, has one angle, 2 has two angles, 3 has three and so on.

Words and Number Symbols, and Fibonacci (originally known as Leonardo from Pisa) in the 13th century, who inherited and delivered them to the mass population of Europe. Fibonacci learned of them when he was sent by his father to the city of Bougie, in Algeria, to learn mathematics from a teacher called Sidi Omar who taught the mathematics of the schools of Baghdad and Mosul (which included algebraic and simultaneous equations).

Fibonacci also visited the libraries of Alexandria, Cairo and Damascus, after which he wrote his famous Latin book *Liber Abaci*. The first chapter of this deals with Arabic numerals. He introduced these new numerals in the following words: 'The nine numerals of the Indians are these (from left to right): 987654321. With them, and with this sign '0', which in Arabic is called *cephirum* (cipher), any desired number can be written.'

It was this system of calculating with Arabic numerals which allowed most of the advances in numerical methods by Muslim mathematicians. Now the extraction of roots was possible by mathematicians like Abu al-Wafa' and Umar al-Khayyam. The discovery of the binomial theorem for integer exponents by al-Karaji was a major factor in the development of numerical analysis based on the decimal system. In the 14th century, al-Kashi contributed to the development of decimal fractions, not only for approximating algebraic numbers, but also for real numbers such as pi. His contribution to decimal fractions is so major that for many years he was considered as their inventor. Although not the first to do so, al-Kashi gave an algorithm for calculating nth roots that is a special case of the methods given many centuries later by Ruffini and Horner, 19th century mathematicians from Italy and England respectively.

Although the Arab mathematicians are most famed for their work on algebra, number theory and number systems, they also made considerable contributions to geometry, trigonometry and mathematical astronomy, which you can read more about in this book.

Trigonometry

IT WAS IN SCHOOL that most of us first flirted with trigonometry, simultaneously being handed a scientific calculator for the first time in order to determine the sines, cosines and tangents of angles. For some of us, perhaps it's more accurate to say only a few, these strange functions were met with fascination and glee, representing the first real encounter with non-trivial mathematics.

In most cases though, the presentation of trigonometry is delivered in the context of problems involving triangles, which quite rapidly becomes rather repetitive and dull. Consequently, many students do not appreciate the crucial relevance and importance of trigonometry in solving more interesting and complex problems in astronomy, cartography and navigation. Now when we merrily determine unknown angles and sides of triangles with full dependence on the calculator, we do not stop to ask how, say, the sine of a particular angle could be worked out without a computing machine, relying on pen, paper and human ingenuity alone.

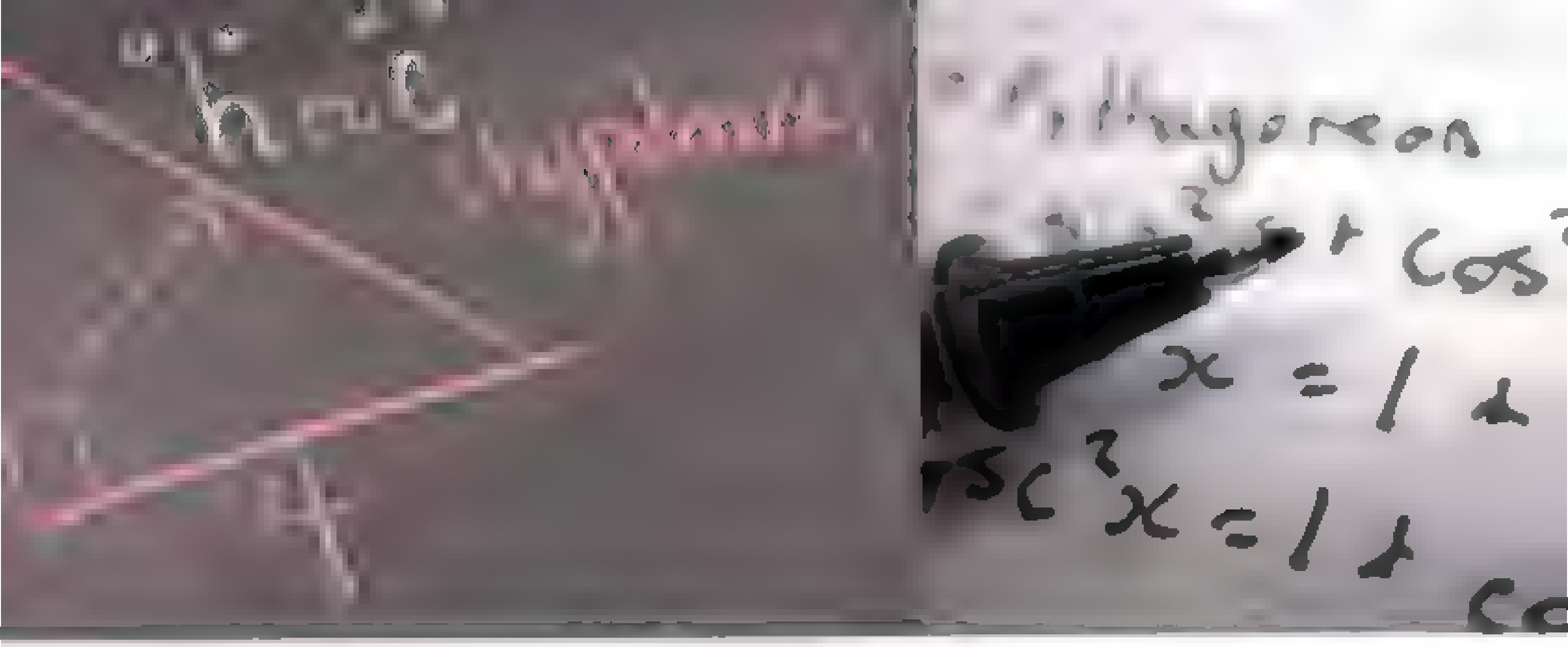
The birth of trigonometry lies in astronomy, one of the sciences studied most vigorously by the Muslims, particularly due to its relevance in determining the exact times of the ritual prayer. But even before the Muslims, Greek astronomers were calculating the unknown sides and angles of certain triangles, given the value of the remaining sides or angles, in order to understand the motions of the Sun, the Moon and the then-known five planets.

Motivated by questions such as the position of the sun, moon and planets, the Greeks composed tables and rules that enabled geometric problems to be tackled. The most thorough treatment of the subject is to be found in the work *Almagest* by Ptolemy, who was an astronomer working in Alexandria in the early part of the 2nd century CE. Ptolemy's treatise reached European scholars via Muslim hands, who translated the original Greek title (which meant *The Great Arrangement*) into more succinct terms to produce *al-Majisti*, simply meaning '*The Greatest*'. This title reflected its highly regarded position in Muslim scholarly circles.

Astronomers from late antiquity would draw principally upon a table found in Book I of *Almagest*, which was called *A Table of Chords in a Circle*, to solve all their plane trigonometric problems. For arcs at angles in increments of half a degree up to 180 degrees, the table gives the lengths of the chords subtending the angles in a circle of radius sixty units.

In his work, *The Transversal Figure*, the 13th century Muslim astronomer al-Tusi explains how this table of chord lengths was employed to solve problems relating to right-angled triangles. Al-Tusi made the crucial observation that established the link between triangles and arcs of circles: any triangle may be inscribed in a circle; therefore, its sides may be viewed as the chords subtending the arcs opposite the angles of the triangle.

But there were two drawbacks to relying on these tables. First, considerable manipulation of the table and intermediate steps were required to solve all the variations that might arise in solving unknown lengths or angles of a right-angled triangle. This is in contrast



to using the six familiar trigonometric functions – the sine, cosine, and tangent and their reciprocals, the secant, cosecant and cotangent – that are characteristic of modern techniques, which were first devised and arranged in a systematic way by Muslim mathematicians. The second inconvenience of the chord length tables is that they often required angles to be doubled in order to calculate the length of an arc.

Actually, a chain of Muslim scholars had already laid the foundations of trigonometry before the 10th century, paving the way for al-Tusi to collect, organize and elaborate on their contributions. It was al-Battani, born in Harran, Turkey, who was one of the most influential figures in trigonometry. He is considered to be one of the greatest Muslim astronomers and mathematicians, eventually dying in Samarra, now in Iraq, in 929 CE. His motivation for pioneering the study of trigonometry was his observation of the movements of planets. You can read more about him in the 'Astronomy' section of the Universe chapter.

More crucially, al-Battani explained his mathematical operations and urged others 'to continue observation, and to search,' in order to perfect and expand his work. As well as al-Battani, Abu al-Wafa', Ibn Yunus and Ibn al-Haitham also developed spherical trigonometry and applied it to the solution of astronomical problems.

Al-Battani was the first to use the expressions 'sine' and 'cosine', defining them as lengths rather than the ratios we know them as today. The tangent was referred to by al-Battani as the 'extended shadow,' the shadow of a notional horizontal rod mounted on a wall. In the 11th-century, al-Biruni defined the trigonometric functions of tangent and cotangent, which were inherited in a tentative form from the Indians.

It is worth mentioning that the Arabic word *Geb* of an angle (this is the ratio of the side facing the angle divided by the hypotenuse), means 'the pocket' which also, in Arabic, means sinus (in an anatomical sense) and this found its way into Latin (*sinus*) and English (sine).

Al-Biruni, born in 973 CE, was among those who laid the foundation for modern trigonometry, al-Khwarizmi, born in 780 CE, developed the sine, cosine and trigonometric tables, which were later translated to the West

It would be another five hundred years ... before the trigonometry of tangents was discovered by modern mathematics, and then another one hundred years before Copernicus was aware of it.

It would be another five hundred years, though, before the trigonometry of tangents was discovered by modern mathematics, and then another one hundred years before Copernicus was aware of it.

It is worth mentioning a few of the other important achievements in the area of trigonometry by Muslims, and also the remarkable application by al-Biruni in measuring the circumference of the Earth. The indispensable Sine Law was stated and proved by al-Tusi by drawing upon and cunningly employing elementary ideas of geometry. He then proceeded to apply the law to solve all kinds of problems in a systematic fashion. Abu al-Wafa proved the familiar addition theorem for sines, which is a lot more efficient and elegant when compared to the original statement in *Almagest* involving chord lengths.

Before the advent of computers, it was important to construct accurate tables of key functions for regularly spaced values of the function argument. This was a painstaking and labour intensive procedure in the case of trigonometric tables. It was required, firstly, to have a very precise way of calculating the sine of one degree, and secondly, a set of rules for interpolating based on the tables. Both these issues were the subject of critical investigation by a number of Muslim scholars, such as al-Biruni, Ibn Yunus and al-Kashi. To reach an approximation of the sine of one degree, al-Kashi uses a procedure which in modern parlance is referred to as an iterative method.

The advent of trigonometrical functions and their use in mathematics have revolutionised mathematical sciences, and trigonometry can now be added to the list of essential areas of knowledge mastered by the Muslims and subsequently conveyed to Europe through various routes.

Right: Trigonometry, including spherical trigonometry, is today used in solving complex problems in astronomy, cartography and navigation. A thousand years ago Muslim scholars were pioneering the study of the subject as they observed the movement of the planets, and solving unknown lengths and angles.

Chemistry

MATERIALS LIKE PLASTIC, rayon, artificial rubber and petrol, and medicines such as insulin and penicillin, all stem from the chemical industry of the early Muslims, who were real chemistry revolutionaries.

The word chemistry in Arabic is *kimia*, and Arabic is similar to French in that 'the' or 'al' comes before many words, so with *al* in front, *kimia* becomes *alkimia*. In the West this last 'a' was dropped and the word became 'alchemy'. Alchemy then, for the main Islamic medieval scientists, was not about folklore or occult practices but about chemistry, and until as recently as the 1[illegible] century, they were considered authorities in this science.

There are three people who stand out in Muslim chemistry from a golden era spanning two hundred years: Jabir ibn Hayyan, born in Iran in 722 CE and died in 815, Muhammad ibn Zakariya' al-Razi from Iran in 865 to circa 925, and al-Kindi from Iraq in 801 to 873.

'Why do you spend all your time practicing chemistry?'

'I wanted to enrich my colleagues and brothers.'

Reply by Khalid ibn [illegible]

[illegible]

Distilled rose water was extensively used in cosmetics and delicatessen

Jabir ibn Hayyan or Geber

Jabir ibn Hayyan was known in the west as Geber, and all scholars unanimously agree that he is the founder of chemistry. The son of a druggist, he spent most of his life in Kufa, Iraq, where he scientifically systemized chemistry. Constantly in the laboratory, he devised and perfected sublimation, liquefaction, crystallization, distillation, purification, amalgamation, oxidation, evaporation, and filtration, produced sulphuric acid by distilling alum; and began the classification of materials into spirits, metals and minerals. He also wrote about how chemicals combined, without loss of character, to form a union of elements together that were too small for the naked eye to see. Now this may seem like common sense but over twelve hundred and fifty years ago, he was a man ahead of the times.

The most important research of this really remarkable experimenter had to do with acids. The ancient world had no knowledge of any acid more powerful than acetic, an acid that gives vinegar its characteristic taste. Jabir vastly increased the possibilities of chemical experiments by discovering sulphuric, nitric and nitromuriatic acids, all now vitally important in the chemical industry.

He also built a precise scale which weighed items 6,480 times smaller than the ratl (ratl=1 kg), and noticed that in certain conditions of oxidation, the weight of a metal was lessened.

Some of Jabir ibn Hayyan's writings include the *Great Book of Chemical Properties*, *The Weights and Measures*, *The Chemical Combination*, and *The Dyes*. These works described the use of the water bath and the chemical oven, and he discussed important chemicals like oxide of mercury and suphur compounds.

The practical application of chemistry interested him, because he, like many Muslim scholars, wanted to better his society. He also seemed to be incredibly curious and researched the dyeing of cloth and leather, preparation of hair dyes, varnishes to make cloth waterproof and protect iron, manganese dioxide in glassmaking, iron pyrites for writing in gold; salts for glazing tiles and ceramics, and the distillation of vinegar to concentrate acetic acid. He even invented a kind of paper that resisted fire and an ink that could be read at night.

Jabir's work with metal refinement and the preparation of steel helped develop foundry techniques. Among his greatest contributions to the theory of chemistry were his views upon the constitution of metals and these survived with slight alterations and additions until the beginning of modern chemistry in the 18th century.

All this research was carried out in his laboratory in Kufa, Iraq which was rediscovered about two centuries after his death during the demolition of some houses in the quarter of the town known as the Damascus gate. Found among the rubble was a mortar and a large piece of gold.

The distillation process from an 18th century Arabic treatise on chemistry. The Arabic text refers to the various vessels and the alembic, describing how the condensation is conveyed from the upper cooling vessel to the recipient flask.

Ninth century chemist al-Razi depicted in his Baghdad laboratory. Modern perfumes would not exist today without the distillation process, devised and perfected by Jabir ibn Hayyan in the late 8th century.

Al-Razi or Rhazes

Muhammad ibn Zakariya' al-Razi was known in the West as Rhazes, and he wrote *The Book of the Secret of the Secrets*. It may sound like a wizard's handbook but actually dealt with the preparation of chemical substances and their application. In this, he proved himself to be a greater expert than all his predecessors, including Jabir, in the exact classification of natural substances. He divided them into earthly, vegetable and animal substances, while also adding a number of artificially obtained materials like lead oxide, caustic soda and various alloys. Before him Jabir had divided mineral substances into bodies (like gold and silver), souls (like sulphur and arsenic) and spirits (like mercury and sal-ammoniac).

He also excelled in writing up his experiments, explaining all the processes and apparatuses used. From his *Secret of the Secrets* we know he was performing distillation, calcination and crystallization over eleven hundred years ago.

He is also recognized for laying down the firm foundations of modern chemistry by setting up, for the first time, a laboratory in the modern sense. He designed, described and used more than twenty instruments, many of which are still in use today, instruments like the crucible, cucurbit or retort for distillation and the head of a still with a delivery tube, plus various types of furnace or stove.

Al-Kindi

A lot of al-Kindi's work was translated into Latin, by men like Gerard of Cremona, so today there is more in Latin than Arabic. For instance, there is *De gradibus*, in which al-Kindi explains that the complex of a compound medicine could be mathematically derived from the qualities and degrees of its component samples, and that there was a geometrical relationship between increasing quantity and degree of effectiveness.

Al-Kindi also wrote *Book of the Chemistry of Perfume and Distillations*. For more on perfume read 'Cleanliness' in the Home chapter.

Like much of the knowledge built up in the Muslim world, it did not stay there, but, like all good ideas, it spread around the globe. It was translated into Latin and even into local languages, which explains its spread to Europe. The Italian, Gerard of Cremona, made the more valuable translations like al-Razi's *De aluminibus et salibus*, a study and classification of salts and alums (sulphates).

important scientists of 13th-century Europe, like Albertus Magnus and Roger Bacon, came to know about these works. Roger Bacon particularly believed in the great importance of chemistry which he discovered from the Latin translations of Arabic works.

This huge translation process, from Arabic to Latin, began in the middle of the 12th century. One work of Jabir's, *Liber Claritatis*, appeared in the last third of the 13th century. Around the year 1300, another of Jabir's books, *Summa Perfectionis Magisterium* or *Sum of Perfection* was translated into Latin. This book is usually accompanied by four other treatises called *De investigatione perfectionis* or *The Investigation of Perfection*, *De inventione veritatis* or *The Invention of Verity*, *Liber fornacum* or *The Book of Furnaces*; and the *Testamentum* or *Testament*. These treatises were frequently printed together in one volume between the 15th and the 17th centuries. In short they were all known as *The Summa* and it was so successful that it became the main chemical textbook of medieval Europe. This manual on general chemical literature remained unrivalled for several centuries.

It is easy for us today to relegate scientists of a millennium ago to some dusty outdated room high in a tower, surrounded by smoking and bubbling pots, using strange concoctions. In reality, they were highly scientific experimenters, the very equivalent of today's leading laboratory minds, who are also laying the foundations for our futures and descendents.

To read more about chemical processes and the impact that a thousand years of Muslim chemistry has had on today's industries go to the Town chapter and 'Commercial Chemistry' section.

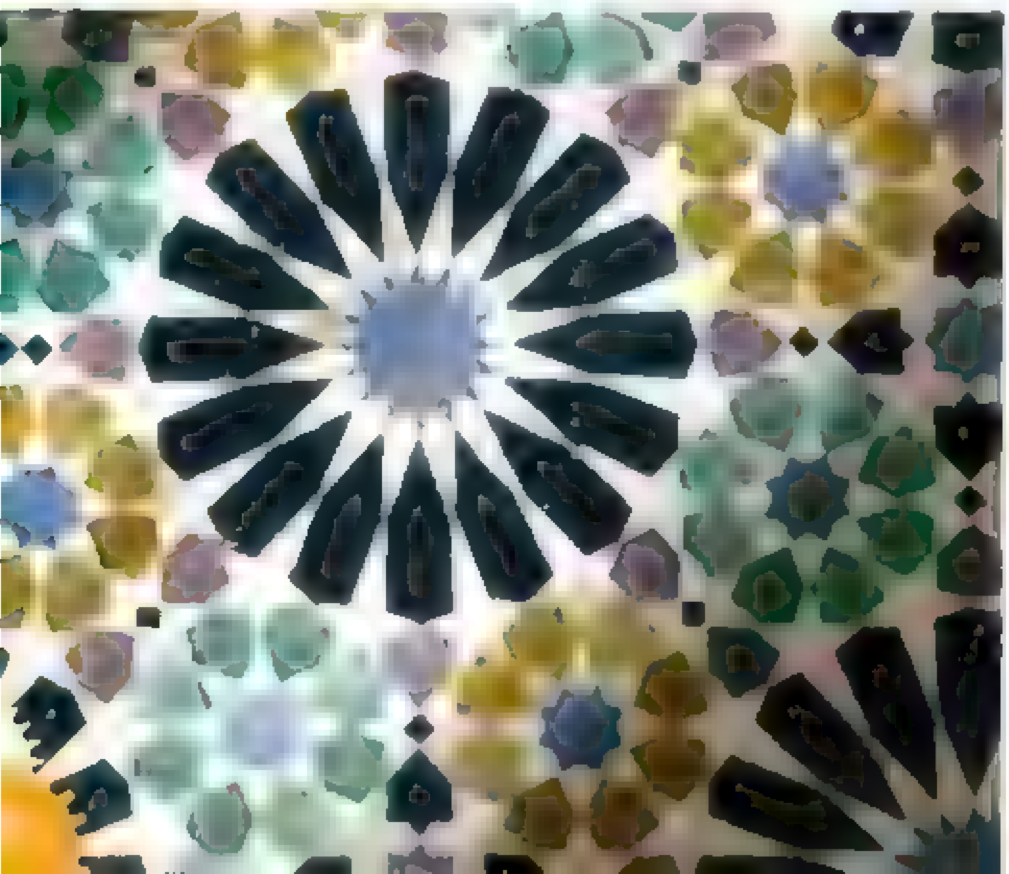
Geometry

Muslims are famous for intricate and elegant geometrical designs decorating their historic buildings which you can read more about in the 'Art and Arabesque' section of this chapter. These wonderful designs could not have happened without leaps made in geometry, or the measurement, properties and relationships of points, lines, angles and 2-D and 3-D figures.

Scholars inherited, developed and extended geometry from the Greeks who took a keen interest and Euclid spent a lot of time on it in the *Elements*. For most avid mathematicians their starting point into geometry is through Euclid's monumental and timeless work.

The investigations Muslims undertook in geometry rested on three Hellenist pillars. The first was Euclid's *Elements*, which was translated in Baghdad in the 8th-century House of Wisdom. The second was two works of Archimedes, *On the Sphere and Cylinder* and *The Heptagon in the Circle*. Now, this second one is unavailable in Greek and reaches us through the Arabic translation by Thabit ibn Qurra. The third and final pillar is the difficult work of Apollonios of Perga, called *The Conics*. This appeared in eight books, written around 200 BCE. Only four of these survive in Greek, while seven came to us in Arabic.

Tiles from Alhambra Palace, Granada, Spain. Most Islamic [illegible] designs have geometrical [illegible]



Most of the geometrical constructions of both the Greek and Islamic worlds were unified under the theory of conic sections, which were used in geometrical constructions, the design of mirrors for focusing light and the theory of sundials. The surface of a solid double cone is formed by extending out straight lines (generators) that radiate out of the circumference of a circle, called the base, and pass through a fixed point, denoted the vertex, not on the plane of the base. Conic sections are generated by cutting the double cone by a plane intersecting the generators. The shape of the plane section that remains is determined by the angle of the plane to the generators. Apollonios successfully argued that, other than the circle, only three kinds of conic sections could be generated: the ellipse, the parabola and the hyperbola.

Abu Sahl al-Kuhi used the theory of conic sections to develop a remarkable procedure for the construction of a regular seven-sided

polygon, the heptagon. Abu Sahl al-Kuhi was one of a group of gifted scientists who were brought together from all over the eastern segment of the Muslim world under the auspices of key members of the influential Buyid family in Baghdad. Emerging from the mountainous regions south of the Caspian Sea, and originally a juggler of glass bottles in the *souk* (market) of Baghdad, Abu Sahl al-Kuhi turned his attention to the study of the sciences. He was interested in the work of Archimedes, writing a commentary on Book II of *On the Sphere and Cylinder*. His main focus lay in conic sections and their use in solving problems related to the construction of complex geometric objects.

For instance, he explained how it was possible to construct, with conic sections, a sphere with a segment similar to a segment of one sphere and possessing a surface area equal to a segment of a second sphere. He elaborated on a new instrument that could be used for drawing conic sections, 'the complete compass.' But Abu Sahl al-Kuhi had set his sights on even greater ambitions, detailed instructions for the construction of the regular heptagon. Archimedes had supplied a proof relating to a regular heptagon inscribed within a circle that suggests that it ought to be possible to construct a heptagon, but this didn't go quite far enough to provide an actual procedure.

This is quite common in the abstract universe of mathematics. Occasionally, it is very difficult to derive a step-by-step procedure for the construction of certain mathematical objects. In such situations, mathematicians concern themselves with proving that at least such a procedure exists, leaving the discovery of the detailed procedure to others.

Even though Archimedes gave proof of the existence, the actual construction of the heptagon eluded the best Greek and Muslim mathematicians for centuries, so much so that the 10th-century Muslim scholar Abu al-Jud remarked that 'perhaps its execution is more difficult and its proof more remote than that for which it serves as a premise.' Cue Abu Sahl al-Kuhi to take up this challenge. Through deft manipulation, Abu Sahl al-Kuhi was able to tame the beast, reducing the problem to three steps, which, if reversed, would lead to the construction. He said start with the construction of a relevant conic section based on the length of the side of the heptagon. Then generate a divided line segment according to given proportions, and from the divided line segment, form a triangle possessing certain properties. Finally, produce the heptagon from the constructed triangle.

Abu Sahl is also known for his discovery of a method for trisecting a given angle. This was

referred to as 'the lemma of Abu Sahl al-Kuhi' by Abd al-Jalil al-Sijzi, a younger contemporary of Abu Sahl, and used in the construction of a regular nine-sided polygon, the nonagon.

Knowledge of conic sections was required by instrument makers to engrave them on the surfaces of sundials. The Greeks knew 'that as the sun traces its circular path across the sky during the day, the rays that pass over the tip of a vertical rod set in the earth form a double cone, and, because the plane of the horizon cuts both parts of this cone, the section of the cone by the horizon plane must be a hyperbola.' This motivated the likes of Ibrahim ibn Sinan, the grandson of Thabit ibn Qurra, to make a study of the subject. His life was cut short due to a liver tumor and he met his demise at the early age of thirty-seven in 946. Yet, 'his surviving works ensure his reputation as an important figure in the history of mathematics,' says J.L. Berggren, a contemporary writer. He then summarizes Ibrahim ibn Sinan's achievements:

'His treatment of the area of a segment of a parabola is the simplest that has come down to us from the period prior to the Renaissance … in his work on sundials, he treats the design of all possible kinds of dials according to a single, unified procedure, and it represents a fresh, successful attack on problems that had often defeated his predecessors.'

In relation to practical geometric design, which would be used to embellish the likes of such public buildings as mosques, palaces and libraries, Muslim geometers were interested in justifying the craft of the artisans and exploring the limits of their art. Abu Nasr al-Farabi (d. 950), better known for his work on music, philosophy and his commentaries on Aristotle, wrote a treatise of geometric constructions from tools with various restrictions. His work was titled, rather exotically, *A Book of Spiritual Crafts and Natural Secrets in the Details of Geometrical Figures*. This contribution of al-Farabi was later incorporated by Abu al-Wafa', in his youth when al-Farabi died, in his book *On Those Parts of Geometry Needed by Craftsmen*, providing full constructional details and justifications.

The kind of problems to which Abu al-Wafa' devoted his attention included constructing a perpendicular to a given segment at its endpoint, dividing a line segment into any number of equal parts, and constructing a square in a given circle and various regular polygons (with 3, 4, 5, 6, 8, 10 sides). All these constructions were to be carried out with nothing more than a straight edge and a 'rusty compass,' a compass with one fixed opening.

Geometry had special significance also for Muslim artists, architects and calligraphers. They had a keen awareness of the affinity between measurements in nature and mathematical expressions, and they were constantly inspired by these deep connections.

Such measurements included the Golden Ratio, a ratio of measurements that's pleasing to the eye and appears a lot in nature, such as in mollusc shells and plant leaves. In layman's terms, it means the width of an object is roughly two thirds that of its height, or approximately 1.618. It is also called a

Left: Measurements in nature have mathematical expressions which inspired the scholars. One of these is the golden ratio which is expressed in mollusc shells, plants and flowers.

golden section or line, so that if a line is divided, the smaller part of the line is to the larger part of the line as the larger part is to the whole line. This turns out to be approximately the ratio of 8:13 and is visible in many works of art and architecture.

As well as being fascinated by these geometrical occurrences, artists were also looking for the centre of any system of 'chaos,' so this concept of centre in terms of proportion remained their focus too.

The *Ikhwan al-Safa*, or Brothers of Purity, were a group of scholars in the 10th century CE, who recorded their ideas about proportion in their *Epistles* or *Rasa'il*. They knew of the Roman canon of Vitruvius, a 1st-century BCE architect and writer, who measured the human body as a system of proportion. It was this idea the *Ikhwan* considered to be defective, as it was centred on the sacrum or the groin, instead of the navel.

Vitruvius's findings were based on a Greek canon, and this was founded on an ancient Egyptian rule of proportion, which related to the backbone of the god Osiris. The 'sacred backbone' or *Djet* pillar, was a pre-dynastic representation of Osiris and it represented stability, endurance and goodness.

After painstaking research, the *Ikhwan's* epistles came to a different conclusion. They established that when the human body was stretched and extended out, the fingertips and the tips of the toes touched the circumference of an imagined circle. The centre of this circle was then the navel and not the groin, if the body was that of a child under age seven. This perfect proportion, with the navel being the centre, begins to be disproportionately placed after the age of seven; the age of innocence. At birth, the mid-point of the body is at the navel. As the individual grows the mid-point drops until it reaches the groin or sacrum.

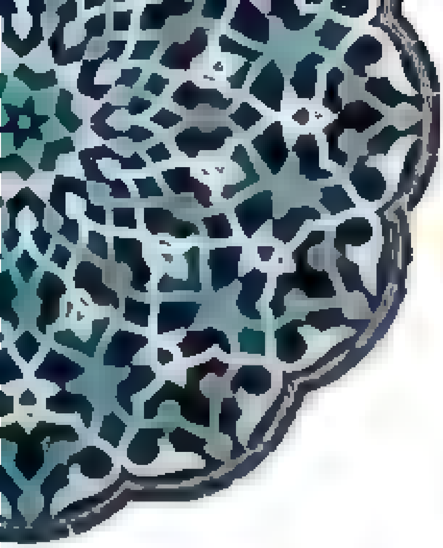
The proportional ratio produces an ideal figure for religious painting. The width is eight spans, the height is ten spans and the mid-point is on the navel. The division of the figure is a body eight heads long, a foot is an eighth of a body, the face is an eighth of a body, the forehead is a third of the face, a face is four noses or four ears.

With the navel as the centre of the circle, which represented the Earth, and the place of life sustenance, this demonstrated a divine manifestation. These divine proportions were reflected in cosmology, musicology and calligraphy, and in all arts from the 10th century. They were seen as the key to finding harmony and, for the mystics, closeness to God.

For example, the natural harmony of the figure of eight was seen by Muslim scholars as the basic number which motivated them to make measurements in music scale, poetry, calligraphy, and artistic themes.

There is, of course, the whole fascinating area of the algebraic geometry of Umar al-Khayyam, and the geometric theory of lenses by al-Tusi, which were both new fields of geometry. To read more about these go to the sections on 'Mathematics' in School, and 'Vision and Cameras' in the Home chapter.

Leonardo da Vinci's *Vitruvian Man* shows the proportions of the human body, which were discussed in the 10th-century *Epistles* of the *Ikhwan al-Safa*.



Art and the Arabesque

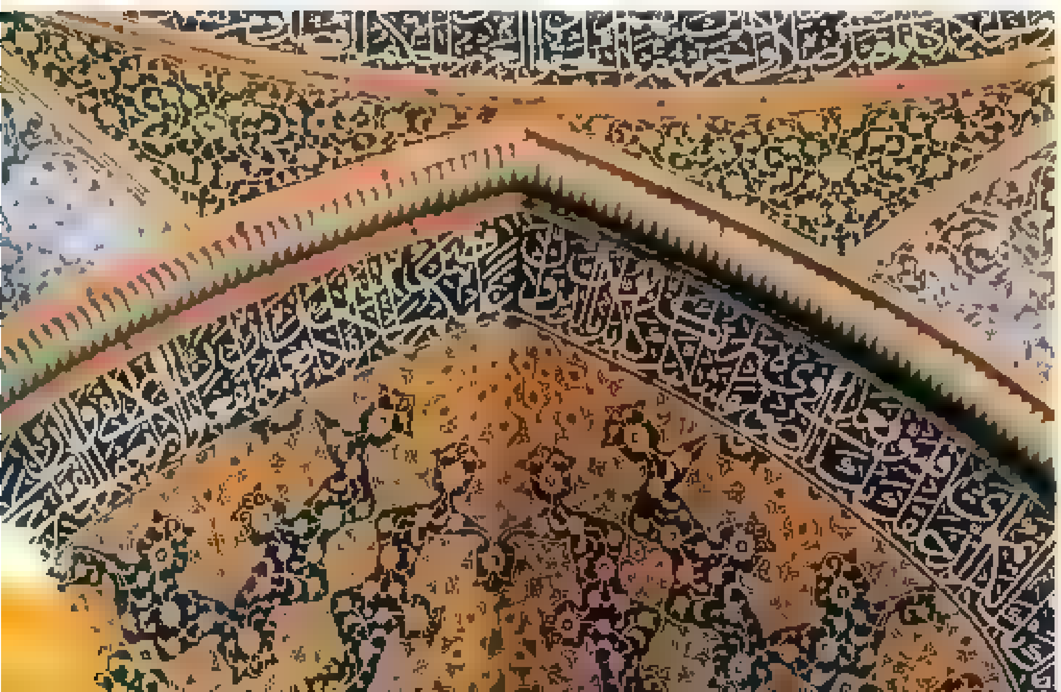
You can gaze into some art designs and with each blink of an eye you see different shapes and forms. This type of geometric art is a fusion of pure mathematics and the art of space, an interplay of shapes and repeating patterns. It has no figures of people, but is made of flowing lines in complex designs. These designs seem to change as they are looked at, encouraging deep thought and spiritual contemplation, and, because of this, they fitted well into mosques.

Prophet Mohammad (pbuh) spoke out against the portrayal of human or animal forms in art. He didn't want Muslims at the time to revert to worshiping idols, figures or the material world, a pre-Islamic practice which would take attention away from God.

Geometry became central to the art of the Muslim world. Artists freed their imagination and creativity to produce a totally new art form called the arabesque, a development of geometric art.

Arabesque is a pattern of many units joined and interlaced together, all flowing from the others in all directions. Each independent unit is complete and capable of standing alone, but all are interlinked and form a part of the whole design. These 2-D designs were mostly used to decorate surfaces like ceilings, walls, carpets, furniture and textiles.

The Lotfollah Mosque in Isfahan, Iran beautifully shows arabesque and interwoven monumental cursive style calligraphy (above and below the pointed arch) of Quranic verses.



Clockwise: The Topkapi scroll from the late 15^{th} or 16^{th} century, showing individual geometric patterns for wall surfaces and vaulting compiled by a Persian master builder; King Henry VIII (ruled 1509–1547) with the Islamic 'knot' style pattern on the border of his cloak and curtain. He is standing on a Turkish carpet with its *Ushak* star; ceramic tiles with the *Iznik* blue patterns at Topkapi Palace in Turkey

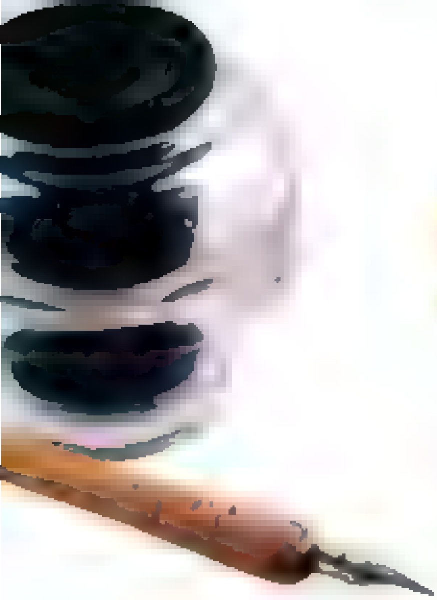
Outstanding examples of this sophisticated art form were recently discovered when the Topkapi scroll was uncovered in Istanbul. The scroll, with its 114 individual geometric patterns for wall surfaces and vaulting, is the work of a master builder who worked in Persia during the late 15^{th} or 16^{th} century. It is the earliest of its kind to have been found intact. Before its discovery, the earliest known Islamic architectural scrolls were fragments from the 16^{th} century around Bukhara, Uzbekistan.

Arabesque can also be floral, using a stalk, leaf, or flower, or a combination of floral and geometric patterns, and these designs equally fascinated European artists. Works from the Renaissance, Baroque, Rococo, modern art (particularly in the grotesque), and strapwork all featured the patterns.

Leonardo da Vinci found arabesque fascinating, and used to spend considerable time working out complicated patterns. The famous knot design was used by King Henry VIII, and it appears in his portrait on the border of his cloak and the curtains. Durer used geometric patterns, as did Raphael. The grotesque designs of 17^{th} century French artist Jean Berain show it, and 16^{th} century Italian artists called it '*rabeschi*'.

One of the best known 20^{th} century artists inspired by geometric art was the Dutchman M.C. Escher. He created unique and fascinating works of art that explored a wide range of mathematical ideas, and not surprisingly he drew his inspiration from the tile patterns used in the Alhambra, which he visited in 1936. He spent many days sketching these, and later said that this 'was the richest source of inspiration that I have ever tapped'.

It wasn't only the Arabesque that came to Europe, because in the 14^{th} century an important breakthrough for European Artists took place. From the Muslim world they imported oil paint. In the past they had only used tempera paint on wood panels, which was a substance made of a combination of egg, water, honey and the dye. The expensive linseed oil paint had a dramatic effect on European paintings as it enhanced the colour saturation of Flemish and Venetian pictures.



The Scribe

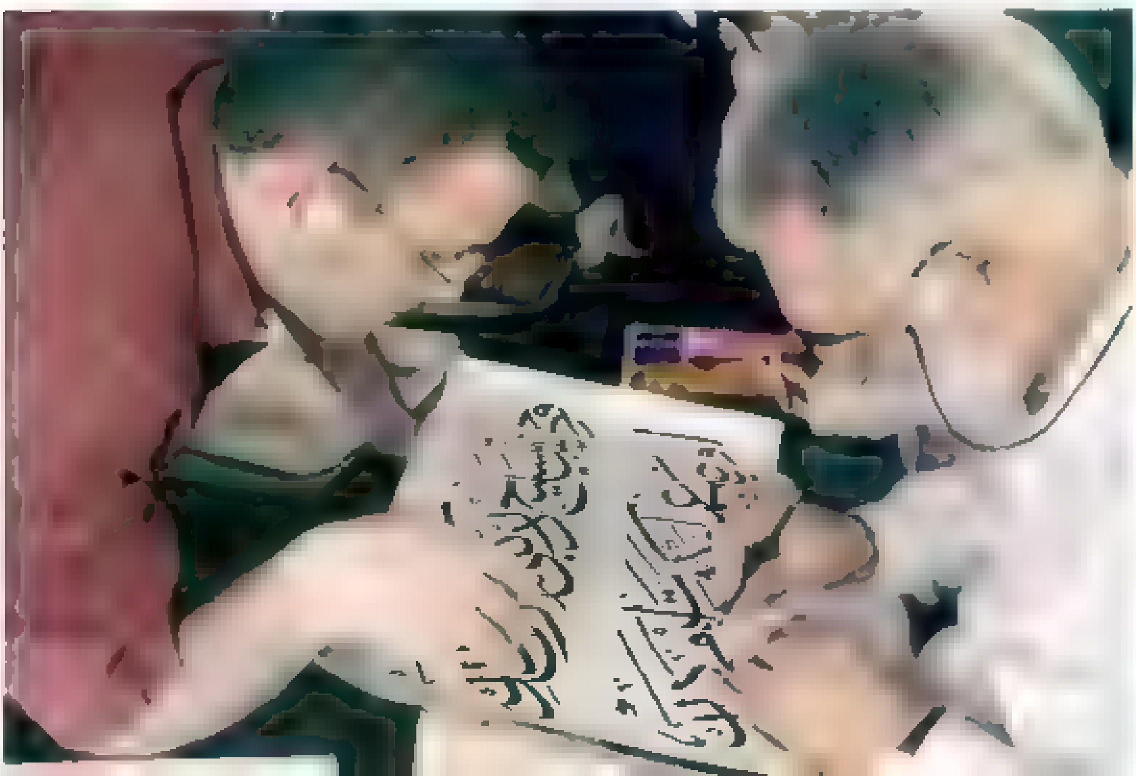
TAKE YOURSELF BACK TO THE CLASSROOM and your textbook where you had to repeat, line after line, letters and words to perfect their shape. Not all of us had the talent of producing artistic or even neat writing, using letters by themselves or joined up. The art of writing, with the beautiful and flowing text of calligraphy illustrates the Quran, the Muslims' Holy Book, famous statements and proverbs.

There are many types of decorative writing, like Egyptian hieroglyphics or Chinese and Japanese script, but Arabic calligraphy developed independently from all of these. It was around even before Islam in the 7th century, but Muslims significantly developed it. They used it in art, sometimes combined with geometrical and natural figures, but it was also a form of worship, as the Quran promises divine blessings to those who read and write it. With the pen as a symbol of knowledge, the art of calligraphy was an art in the remembrance of God.

With this great impetus to write artistically, a final ingredient gave calligraphy another popularity boost. This was the mystical power attributed to some words, names and sentences as protections against evil.

The language of Arabic calligraphy belongs to the family of ancient Semitic languages, and it comes in many scripts, the most famous of which are, *Kufic* and *Naskh*.

The *Kufic* script comes from the city of Kufa, Iraq, where it was used by scribes transcribing the Quran in the Kufa school of writing. The letters of this script are angular



World famous Turkish calligrapher Hasan Celebi instructing a student

An ancient *Kufic* script of two Quranic verses (21 and 22, chapter 31)
The circle in the centre signifies the separation between the verses

The *Naskh* script is older than *Kufic*, but it resembles the characters used by modern Arabic writing and printing. It is joined up, a cursive script, and round, and has a few semi styles. As early as the 10th century, the famous calligrapher Abu 'Ali ibn Muqla devised a systematic classification of the script according to geometric principles, establishing a unit of measurement for letters and creating a balance among them. He counted six cursive scripts which became known as *al aqlam al-sitta*. *Naskh* calligraphy became more popular than *Kufic*, which was developed by the Ottomans.

What to write on was given great importance, and before paper was introduced, parchment and papyrus were the main materials for copying the Quran, writing manuscripts and correspondence. Parchment was durable, lustrous, and luxurious, though only one side could be used. Papyrus was brittle and could not be erased, which made it useful especially for government records. But both were expensive, so when the cheaper alternative, paper, was introduced in the late 8th century the art of writing boomed.

Paper was easily cut, shaped and pasted. It absorbed colour better than either parchment or papyrus. Papyrus was still occasionally used until the 11th century, and the Quran continued to be written on parchment for a long time. For most works though, paper became the new medium of books, letters, official and private correspondence, and it was on paper that nearly all inventions and changes in the Arabic script took place.

Not just paper was used to write on, almost any object can carry script, and calligraphy was also used on marble, brickwork, glass, textile, ceramics, woodwork, metal, and precious and semi-precious stones.

Right: The first chapter of the Quran in *Jali Diwani* style gilded by master gilder Mamure Öz from the Topkapi Palace in Istanbul.

Below: Reed pens used in calligraphy. The nib of each is cut specifically to suit the different style of writing.

Europe came into contact with Arabic calligraphy through trade and gift exchange between European and Muslim royal courts. At first, Europeans imitated Arabic calligraphy without knowing what it said, and *Kufic* inscriptions from the Ibn Tulun Mosque, built in Cairo in 879 CE, were reproduced in Gothic art, first in France, then in the rest of Europe. Works like the carved wooden doors made by the master carver 'Gan Fredus' in a chapel of the under porch of the Cathedral of Le Puy in France, and another carved door in the church of la Vaute Chillac near Le Puy are also attributed to the influence of the Ibn Tulun Mosque. Traders from Amalfi in Italy who visited Cairo are believed to be responsible for the transmission of these designs into Europe as they had special relations with Fatimid Cairo at that time.

In his book *Legacy of Islam*, Professor Thomas Arnold said that a cross that probably dates back to the 9th century was found in Ireland with the phrase called the *Basmalah* (*bi ism Allah*) or 'In the name of God' inscribed in *Kufic* calligraphy on it. In other art forms, especially painting, *Kufic* inscription was added for style. People were drawn to calligraphy, even the Renaissance painter, Gentile da Fabriano, used it to decorate clothing edge bands of his people in his painting *Adoration of the Magi*.

Before pens, as we know them today, came other writing instruments including the *qalam* or reed pen. The most sought-after reeds came from the coastal lands of the Arabian Gulf and they were valuable trading commodities. Their length varied between twenty-four and

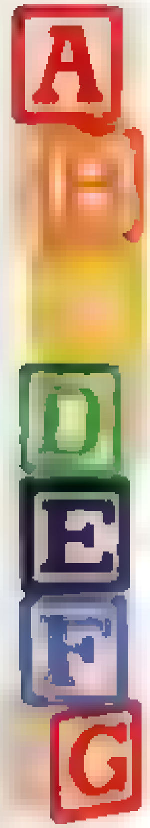
thirty centimetres and their diameter generally measured one centimetre. Each style of script required a different reed, cut at a specific angle.

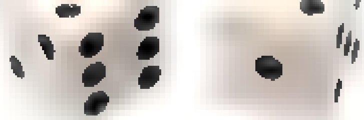
Inks were in different types and colours with black and dark brown inks being most often used, all differing in intensity and consistency. Calligraphers usually made their own inks, and sometimes the recipes were closely guarded secrets. Silver and gold inks were used on blue vellum, in frontispieces, for illustrations, and for title pages. Coloured inks such as reds, whites, and blues were sometimes used in illuminated headings. Ink pots, polishing stones and sand for drying the ink were additional accessories used by calligraphers and scribes in their trade.

Even with the advent of computers, the art of writing is not dying and nothing can replace the work of a skilled hand, a carved pen and flowing ink. Calligraphy today takes its shapes on wedding invitations, music albums, postcards and signs. It is still being used for writing the Quran, and also illustrates books from art and architecture to poetry and technology.

'The beautiful writing strengthens the clarity of righteousness.'

[illegible]





Word Power

LEARNING YOUR ALPHABET will take you back to your nursery school and the following alphabet comes with a twist, looking at the roots of some English words. These words have come from an Arabic source or they are words used by Arabic speakers that have passed into the English language with their original meaning. It is only a small selection as the actual list carries on into the thousands.

A is for **admiral**, from *amir al* 'commander of…,' like *amir al bahr* 'commander of the seas'. When the Romans adapted amir al, they smuggled in their own Latin prefix ad-, producing admiral. When this reached English, via Old French, it still meant 'commander,' and it was not until the time of Edward III that a strong naval link began to emerge; and for **arsenal**, from *dar al-sinaah* meaning 'house of making/industry' like a factory. This was borrowed into Venetian Italian where the initial d was not pronounced and became *arzana*, which was applied to the large naval dockyard in Venice. The dockyard is known to this day as the Arzenale. English acquired the word either from Italian or from French *arsenale*, using it only for dockyards. By the end of the 16th century it was coming into more general use as a 'military storehouse'.

B is for **barbican**, from the Arabic *bab al-baqarah* 'gate with holes', and for **ballyhoo**, from *bi Allah huwa* meaning 'by Allah it is'.

C is for **crimson**, from *qirmazi* which is related to the *qirmiz*, the insect that produced the red dye *qirmizi*; and for **caviar**, which may come from Farsi *kaya-dar* meaning 'having eggs' or from *chav-jar* meaning 'a cake of strength or power' or 'bread of lovers' in allusion to its reputed aphrodisiac qualities. Others think it came from *havyar* in Turkish which means 'fish eggs'.

D is for **dragoman**, an interpreter or guide in countries where Arabic, Turkish or Persian is spoken; from the Arabic *turjuman* and the verb, *tarjama* to interpret.

E is for **El-Cid**, the hero of a Spanish epic poem from the 12th century, from *al Sayyid* meaning 'the lord'.

F is for **Fomalhaut**, the brightest star in the constellation Piscis Austrinus, the Southern Fish, twenty-four light-years from Earth. *fam al-hut* means 'mouth of the fish'.

G is for **ghoul**, from the Arabic *ghul*, meaning the demon, and for **giraffe** from the Arabic *Zarafa*.

H is for **hazard**, from *yasara*, which means 'play at dice'.

I is for **Izar**, a star in the constellation Andromeda, from the Arabic *al-'izar*, meaning the 'veil or covering'.

J is for **jar**, from *jarrah* a 'large earthen vase', and for **jasmin** from the Persian *yasmin*.

K is for **kohl**, from *kuhl*, meaning a fine powder, often of antimony, used in eye ointments.

L is for **lilac**, from the Arabic *lilak*, which was taken from the Persian *nilak* meaning indigo; and for **lemon**, from the Persian *limun*, which means 'lemon'.

M is for **mafia**, from an Arabic word *mahiyah* 'boasting' or 'flashy', i.e. 'the swank set'. In Sicily an unusually ornate and demonstrative cockerel is described as 'mafioso'; and for **mattress**, coming from old French *materas*, which was taken from *matrah*, a 'place where something is thrown' and *taraha* 'to throw'.

N is for **nadir**, a point on the celestial sphere directly below the observer and diametrically opposite the zenith. It comes from *nadir as samt* meaning 'opposite the zenith'.

O is for **orange**, from the Persian *narang* or *narang*, meaning orange.

P is for **Pherkad**, a star in the constellation Ursa Minor, from the Arabic *al farqad*, meaning 'The calf'.

Q is for **qanun**, the ancestor to the harp and zitter, introduced by al-Farabi in the 10th century, but used in Roman times as a free standing instrument.

R is for the chess piece '**rook**', from the Persian *rukh*.

S is for **sofa**, the seat was originally an Arabian ruler's throne and has been in existence since antiquity. Originally *suffah*, meaning 'long bench' or 'divan'; and for **sugar** from the Arabic *sukkar* meaning sugar; and for '**so long!**' from *salam*, a greeting and goodbye meaning peace.

T is for **tabby**, which meant 'silk cloth with striped pattern' and was borrowed in 1638 from the French. They used *tabis*, 'rich watered silk' from Arabic *'attabi*, originally meaning 'manufactured at al-'Attabiyah, a suburb of Baghdad. By 1695 the phrase tabby cat was in use, and tabby as a noun meaning 'striped cat' developed by 1774; and for **talcum** powder, which is from Latin 'talcum, from the Arabic *talq*. It was first used in Medieval Latin as 'talc' around 1317, and in Spanish Talco and French as Talc in 1582. In German it is Talkum.

U is for **Unukalhai**, a star in the constellation of the Serpent, from the Arabic *'unuq al hayyah*, meaning the 'Neck of the snake'.

V is for **vizier**, from *wazir* meaning 'porter, public servant' from the verb *wazara*, to carry; and for **Vega**, the brightest star in the constellation Lyra from the Arabic *al nasr al waqi*, 'the falling vulture'.

W is for **wadi**, a valley or gully that remains dry except during the rainy season, coming from the Arabic *wadi* which means valley.

X in algebra, meaning 'a thing', is an Arabic invention to solve mathematic equations.

Y is for **yoghurt**. The original Turkish word was *yogurut*, but it had become yoghurt by the 11th century. The g is soft in the Turkish pronunciation but hard in English. *Yog* is said to mean, roughly, 'to condense' in Turkish, while *yogur* means 'to knead'.

Z is for **zenith**, the point of culmination or the peak, coming from the Old Spanish *zenit* which was from the Arabic *samt*, meaning 'path', part of the Arabic phrase *samt al-ra's* 'the road overhead', meaning directly above a person's head.

Story Corner

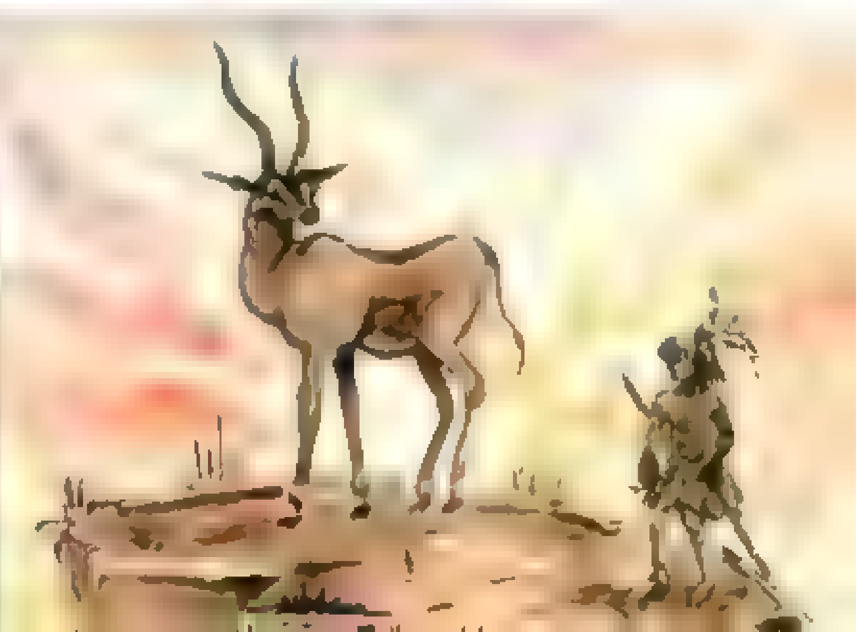
TOM HANKS IN THE FILM *CASTAWAY* played a 21st century shipwrecked character dragged violently from his ordered business world and onto an island, where he had to learn vital skills to keep himself alive. No one visited him for four years. He forged tools from items he salvaged, an ice skate became his knife, a volleyball was his companion and a piece of netting from a fancy dress box trapped fish. But is he really a 21st century re-enactment of Robinson Crusoe or an eight hundred year old character revisited for a third time?

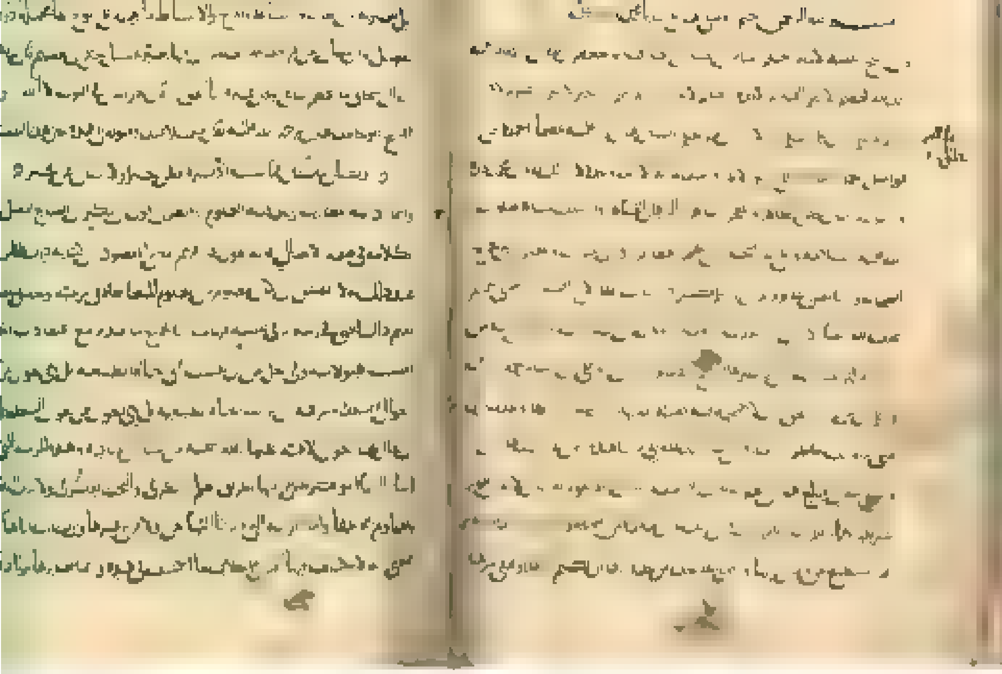
In early 12th-century Muslim Spain, a gifted philosopher, mathematician, poet and medic was born. Ibn Tufayl, or Abu Bakr ibn Abd al-Malik ibn Muhammad ibn Muhammad ibn Tufayl al-Qaysi, to give his full name, became known in the West as Abubacer. He held royal posts as an advisor and court physician, and he is remembered today for *The Story of Hayy ibn Yaqzan*, which is now in the Bodleian Library at Oxford. This tale was inspired by an earlier story from the 11th-century physician philosopher Ibn Sina, who also wrote a narrative called *Hayy ibn Yaqzan* about a century earlier.

Hayy ibn Yaqzan means 'Alive, son of Awake' so this is 'The Story of Alive, son of Awake', which describes Hayy's character passing from sleepy childhood to knowledge and ultimately knowledge, by means of which he can fully contemplate the world and his surroundings.

It begins with Hayy as a child, a princess's son whose birth was secret. He is cast upon the shore of an equatorial island where he's suckled by a doe and spends the first fifty years of his life without contact with any other human beings. His isolation is in seven stages of seven years. During each seven-year stage he is his own teacher and learns about himself and his surroundings.

Left to right: Robinson Crusoe with his man Friday, an illustration by Karima Solberg from Ibn Tufayl's story of *Hayy ibn Yaqzan*, showing him with his adoptive mother, a doe. Daniel Defoe's 18th century *Robinson Crusoe* is almost identical to Ibn Tufayl's 12th century *Hayy ibn Yaqzan*.





Ibn Tufayl's 12th century Arabic manuscript, now in the Bodleian Library, Oxford.

With the death of the doe, he passes from childhood dependency to the activity of an adolescent and then man. Here he faces the dilemma of what life is and what might be ahead behind all that he sees. By solving practical problems and studying subjects from the anatomy and physiology of the animals to the movements of the heavenly bodies, he contemplates the concepts of soul and of the Creator, until eventually he makes the great leap from the intellectual apprehension of truth to the inner, intuitive experience of reality.

Ibn Tufayl begins by describing the experience of truth as the perception of a totally different world, a state of such joy and happiness that one cannot keep it secret, yet cannot find words to describe it. Those with little intellectual capacity may experience this state and talk about it with little comprehension. Others with more intellectual knowledge may achieve a degree of mystical union through their own efforts. By repetition, the state may be prolonged and may occur in daily life, not only during periods of devotion, until it becomes a familiar experience, like meditation. At this stage, the seeker is conscious of truth and of the self. In the succeeding stage, he becomes unconscious of the self and aware only of the holy

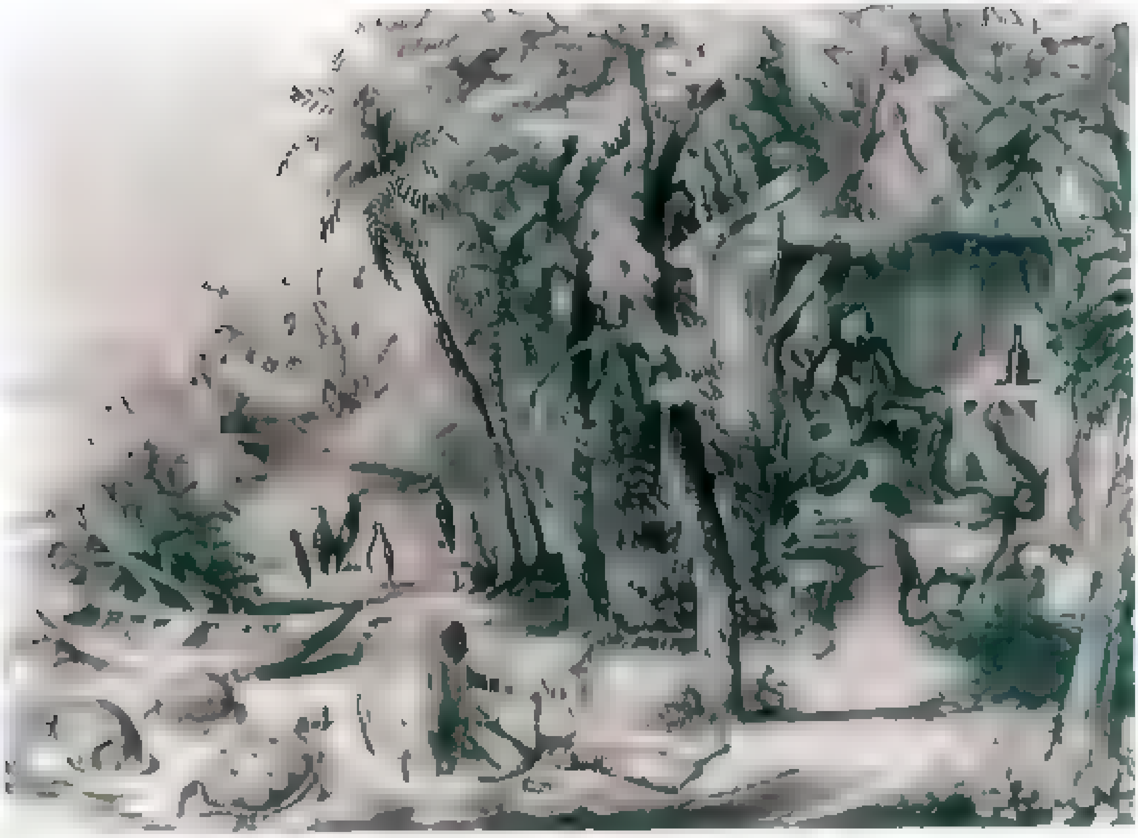
At this monumental point, a man of his own age arrives on the island, and Hayy meets his first human, Asal. Asal is a spiritual and devout person who has come seeking solitude to enable deep contemplation of the truth, which he too has reached by intellectual means.

Asal tells Hayy about his own society, describing organized religion in his homeland. Hayy is inspired, and with the chance arrival of a ship both men visit Asal's island where the conventional approach to spirituality exists under the rule of Asal's friend, Salaman. Hayy wants to tell the islanders about his concept of truth, but he realizes no matter how much he preaches, the experience of truth must come from within. It occurs to him that for the majority of human beings, religion is social and not spiritual. With this realization both Hayy and Asal return to their contemplative lives.

The first English translations of Hayy ibn Yaqzan appeared in 1709, and only eleven years later Defoe's *Life and Strange Adventures of Robinson Crusoe* appeared. Many of Defoe's contemporaries said his inspiration lay in the experiences of Alexander Selkirk, a Scottish mariner who passed over four years in solitude on one of the Juan Fernandez Islands.

The versions of how Hayy got there differ ... versions say that, with some misty history behind it, his mother wanting to save him fron a tyrannical king he was washed onto shore, in a little wooden box, filled with downy feathers

Hayy Ibn Yaqzan t
Tufayl, translated
Daniel Abdal Ha
Moo



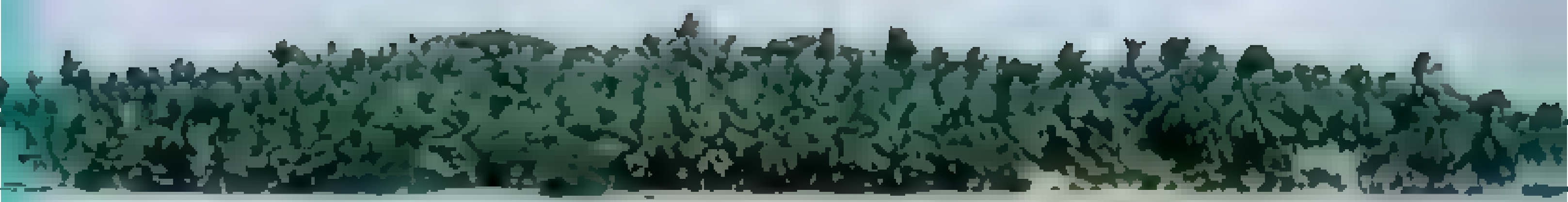
Robinson Crusoe with his pets in an illustration published by Currier & Ives, New York in the late 19th century

The similarities between *Robinson Crusoe* and *Hayy Ibn Yaqzan* are enough to make it probable that Defoe knew the Muslim work. Crusoe is shipwrecked on an island and his solitude teaches him many lessons. He has to solve a myriad of practical problems of how to clothe and feed himself. The solutions he finds, and his struggle for survival can only be successful through the attentive study of his natural world and surroundings. He has to know and understand the climate, the landscape, the vegetation and the animals who share his island.

He goes through psychological anguish as he experiences isolation from human society. These overwhelm and lead him to despair until his exhaustion brings calmness. Only then can the voice of conscience be heard and he senses the presence of the Creator.

Robinson Crusoe's first visitor is not an intellectual, but Man Friday, to whom he passes on some of the lessons he has learned.

The similarities between the two works don't stop with the actual storyline, as the third volume of Defoe's writing on Robinson Crusoe, *Serious Reflections during the Life and Surprising Adventures of Robinson Crusoe, with his Vision of the Angelic World*, also covers a range of moral, religious and philosophical questions. These are very much like, but not as deep, as *Hayy ibn Yaqzan's*.



[illegible] arms, and now walked like a winged thing, commanding space on the forest floor as the bird had commanded space in the air in flight, and the other animals fled from him in fright.

Translating Knowledge

WHAT IS STRIKING ABOUT THE DISCOVERIES, innovations, research and writings of Muslim scientists and scholars, during the European medieval period, is their insatiable thirst for knowledge. This was not knowledge for the sake of knowledge; in most cases it had practical application – improving the quality of life of the people.

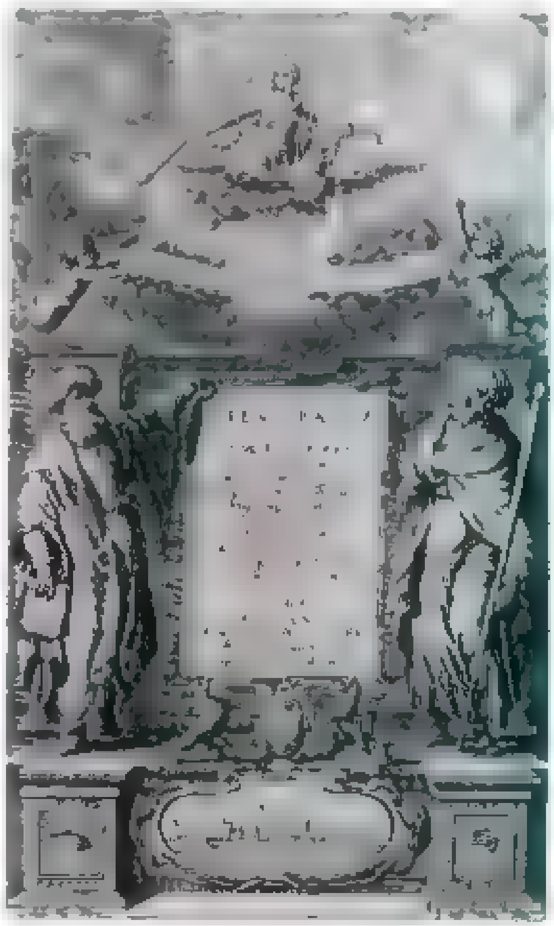
There was also a spiritual influence as Prophet Mohammad (pbuh) had said: 'When a man dies, his actions cease except for three things: a continuous charity, knowledge which continues to benefit people, or a righteous son who prays for him.'

Amazing energy was shown by encyclopaedic individuals who were writing down their findings at incredible rates, filling up enormous tomes with groundbreaking information. Books ran to thousands of pages, numerous volumes and vast libraries. The golden age of this civilization, the 8th to the 13th centuries, saved ancient learning from extinction, modified it, added new discoveries and spread knowledge in an enlarged and enriched form. To read more about great feats of learning and knowledge gathering see the 'House of Wisdom' section above.

At the heart of this understanding was the idea of direct observation. In order to understand how something worked, you had to see it with your own eyes, and only then could you write it down. One man, Ibn al-Haitham, in the late 10th century, did his experiments in complete darkness. Ibn al-Haitham was one of the first people in the world to test his theories with experiments, establishing one of the keystones of all scientific method – prove what you believe! You can read more about him and his experiments in the Home chapter and the 'Vision and Cameras' section.

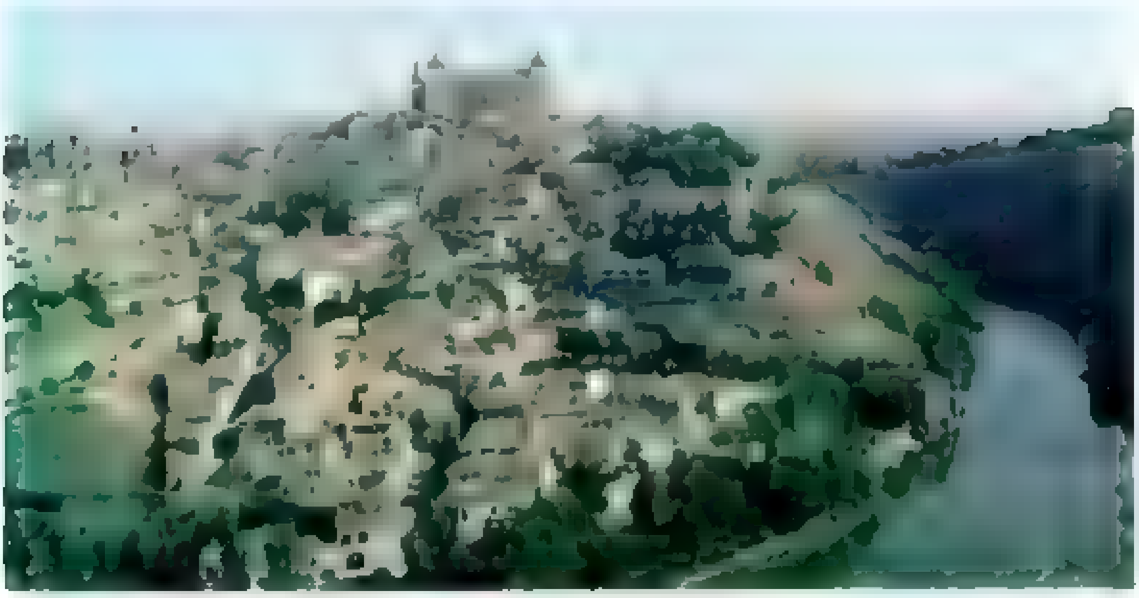
This thirst for knowledge was infectious and even reached its tentacles across oceans touching non-Muslims who flocked to absorb the vast encyclopaedias, based on experimentation that the Muslim polymaths had produced.

Daniel of Morley was an English vicar and scientist, born in c. 1140, from a small,



Right: Ibn al-Haitham, on the left, and Galileo both explored their world through observation and rational thought. This is emphasized here on the front of Johannes Hevelius's *Selenographia*, a 1647 description of the Moon. Ibn al-Haitham's hand is a geometrical diagram while Galileo clutches a long telescope.

A view of Toledo, Spain. In the 12th century, Muslim Toledo hosted simultaneously at least three religions (Muslims, Jews and Christians) as they lived and worked side by side. This melting pot of people and ideas attracted scholars and translators from East and West



sleepy village in Norfolk, who went in search of knowledge. He's just one example of an outward looking and forward thinking European who opened his mind to Muslim knowledge.

Daniel was possibly a student of Adelard of Bath, who had written to the future king Henry II saying 'It happens that you not only read carefully and with understanding those things that the writings of the Latins contain, but you also … wish to understand the opinions of the Arabs concerning the sphere, and the circles and movements of the planets. For you say that whoever has been born and brought up in the hall of the world, if he does not bother to get to know the reason behind such wonderful beauty, is unworthy of that hall and should be thrown out…. Therefore I shall write in Latin what I have learnt in Arabic about the world and its parts.'

To further his education Daniel, like many young students, left his native England, and headed east, first stopping at the University in Paris. Unfortunately, it had become 'stale and moribund' and he could hardly wait to leave. He said 'These masters [in Paris] were so ignorant that they stood as still as statues, pretending to show wisdom by remaining silent.'

So where did he go? Well, in his own words '… since these days it is at Toledo that Arabic teachings are widely celebrated, I hurried there to listen to the world's wisest philosophers.' In 12th-century Toledo at least three cultures lived side by side: Muslims, Jews and Christians. This was a time of cultural richness where all shared the same, breathtaking desire for knowledge. Today the way they worked and lived together is known by the Spanish word as *convivencia*.

What was really exciting for the English clergymen was what was turning up in Toledo, which had been retaken by Christian armies in 1085 CE. Before they'd only had fragments of classical Greek texts, and many of these were forgeries. Now they were hearing that the Muslims had vast resources of the knowledge they yearned for, which wasn't only classical Greek. This had been pulled apart, rebuilt and added to in an immense way by over five hundred years of Muslim scholarship.

'On the Day of Resurrection the feet of the son of Adam [man] will not move away till he is questioned about four matters: how he spent his lifetime, how he spent his youth; from where he acquired his wealth and how he spent it, and what he did with his knowledge.'

Prophet Mohammad (pbuh) narrated by al-Tirmidhi [illegible]

[illegible] together.'

[illegible]porter Rageh Omar presenting the [illegible]

Although thousands of Arabic manuscripts were burnt, there are still over 2500 translated manuscripts (from Arabic to Latin) in the [illegible] Cathedral archives, [illegible] from Daniel of Morley's day.

It was in 12th-century Toledo that possibly the greatest translation effort, from Arabic to Latin, in the history of science took place, which attracted every singleminded scholar and translator of the Christian West. Important works by Greek philosophers and mathematicians, which had been lost in the West, were turning up in Toledo, saved and enhanced by the Muslims. The critique and commentary on Aristotle by Ibn Rushd, known in the West as Averroes, was the real start of Europe's classical revival and this was two hundred years before the Renaissance began.

Many of the commentaries on and summaries of Aristotle's works by Ibn Rushd, writing in Arabic in Cordoba in the late 12th century, were translated into Latin by Michael Scott, a scholar from Scotland who died before 1236, and by his successor, Herman the German. 'These Latin translations, made both in Toledo and Sicily, were destined to set Europe ablaze. He (Averroes) would launch Paris as the intellectual capital of Europe.... Averroes was trying to defuse a conflict between science and religion because the truth revealed by science was often at odds with the truth of divine revelation. This attempt had the opposite effect when his ideas came to the attention of the Christian church. They immediately banned Averroes and Aristotle's works. The Paris intellectuals fought back and a debate raged for years,' says Rageh Omar on the BBC's *An Islamic History of Europe*.

As well as Michael Scott and Daniel of Morley, the city of Toledo was buzzing with contemporary translation scholars. There was also Gerard of Cremona, who was translating important works like al-Zahrawi's thirty-volume medical encyclopaedia into Latin, Ibn al-Haytham's voluminous *Book of Optics*, al-Kindi's treatise on geometrical optics, al-Razi's *De aluminibus et salibus* or

'We ought not to be embarrassed of appreciating the truth and of obtaining it wherever it comes from, even if it comes from races distant and nations different from us. Nothing should be dearer to the seeker of truth than the truth itself, and there is no deterioration of the truth, nor belittling either of one who speaks it or conveys it.'

[illegible]

Today King Peter I's palace in Toledo is a centre for teaching Arabic and Hebrew translation skills. It is a 14[th] century *Mudejar* (the name for Muslims who stayed under Spanish rule) building and, at this time, Jews, Christians and Muslims lived and worked together translating huge scholarly works from Arabic and Hebrew into Latin and Spanish.

A Study and Classification of Salts and Alums (sulphates); and numerous books by the Banu Musa brothers. What's amazing about Gerard of Cremona is that he made over eighty translations but never had a keen grasp of Arabic. Instead, he had to work with and rely on Mozarab locals and the Christian Spanish, who knew the language.

The BBC's *Voices From The Dark* programme says "The process [of translation] varied from translation to translation. Sometimes it was a team helped by a local person with Arabic as their mother tongue. He read the text aloud to an intermediary who also knew Arabic and was expert in Romance, the language which preceded modern Spanish. Then the Romance translation would be put into Latin. Some translators could work alone as they had full command of all three languages."

Even though Alfonso VI had taken the city into Christian hands it remained 'Muslim' in that the lingua franca was still Arabic, spoken by Muslims, Jews and Mozarabs alike; the culture and customs were Muslim, and the architecture was Islamic. Long, winding and narrow streets provided rooms for lodgings and study for all the translators and scholars who arrived. For all these western scholars, Toledo really was the place to be.

Manuscripts of the Latin translations made in Toledo are still in the Toledo Cathedral archives. About 2500 manuscripts are here, including translations from Arabic dating from Daniel of Morley's day.

European Universities

THE OLDEST ENGLISH AND EUROPEAN UNIVERSITIES, where some of us receive our undergraduate and postgraduate degrees, started to appear in the 12th century. They spread quickly from southern Italy and across to England, but why did they suddenly appear?

Muslim learning hit medieval Europe when a massive translation exercise began in the 12th century of Arabic works from the previous five hundred years. The main centre of this translation was Toledo, which you can read about in more detail in this chapter in the 'Translating Knowledge' section.

Before this reservoir of knowledge spilled north, learning in Europe was really kept in the domain of the clergy who mainly studied the Bible. The church was the teaching institute, and to get a good education you had to become a member of the clergy. But scientific or rational thought wasn't encouraged. In fact, if anyone offered a scientific explanation other than one grounded in religion, they would more than likely have been called a heretic and met an unfortunate end.

At the same time in the Muslim lands scientific thought was widely encouraged. So when the Arabic works were translated, the rational thoughts from experiments carried out were made available in Latin to a new audience. This established 'rational scholasticism' in Europe. As you'll discover in this book, one of the main achievements of Muslim scholars a thousand years ago was that they introduced an experimental approach and took nothing for granted. The greatest pressure was from Averroes, as Ibn Rushd was known in the West, whose radical espousal of Aristotle rocked the whole continent, starting with Paris and then hitting the universities of Padua and Bologna. This blew open the whole subject, proving that there didn't need to be any conflict between religion and science.

Left to right: Kings College Chapel, Cambridge University; Al-Azhar University, Cairo, Egypt; Chapel of Exeter College, Oxford University

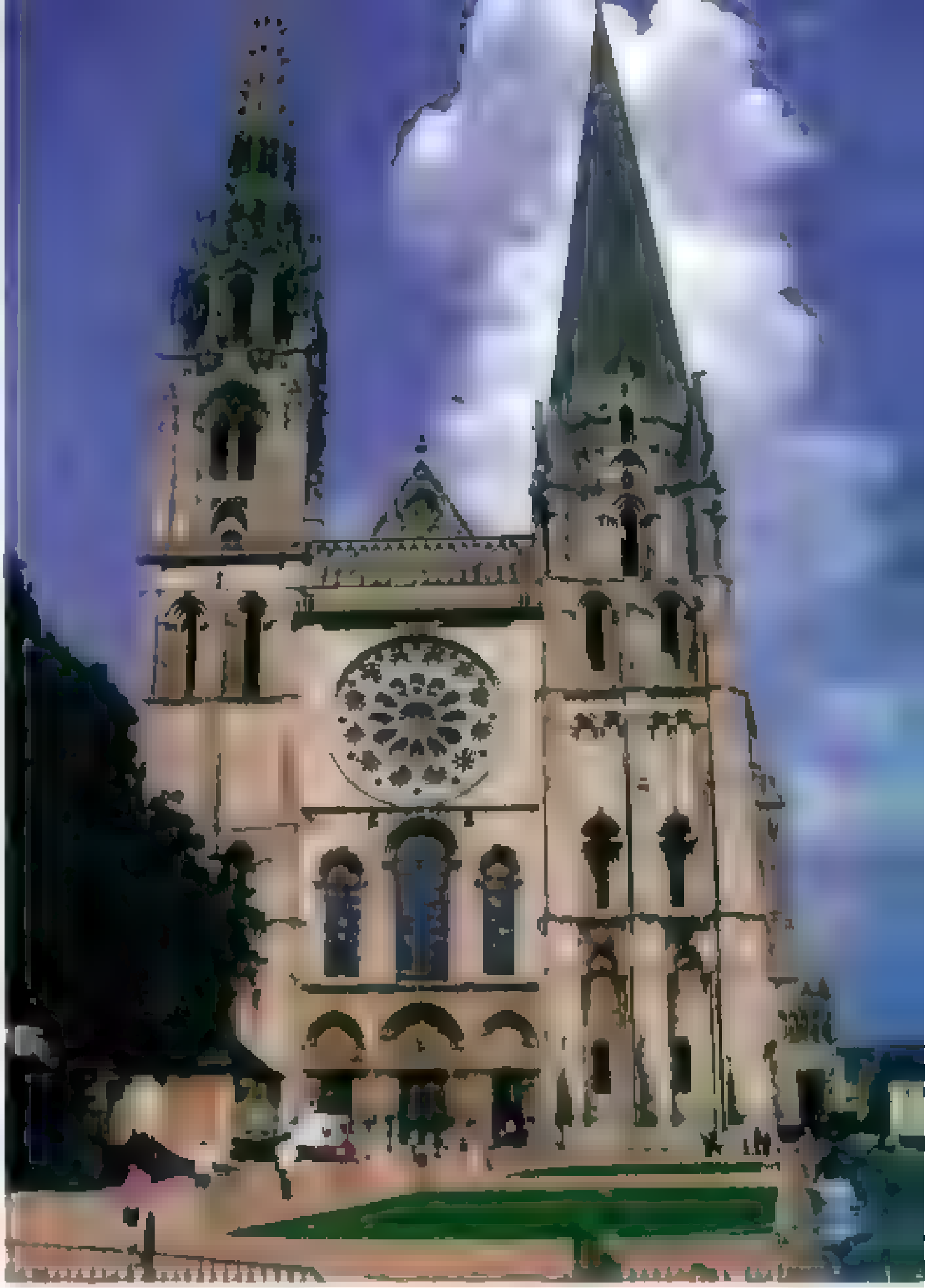
The influx of these Muslim tomes of knowledge, which explored the world and heavens in a rational way, meant that new institutions appeared in Europe. No longer could these new ideas be kept inside the monasteries. So learning shifted from here to cathedral schools. The monasteries had limited students to a particular order, but the cathedral schools gained international reputations drawing students from all over Europe, and producing more independent, liberal thinkers.

One of the new leading institutions was Chartres, a French cathedral school. The work done here paved the way and laid the foundations for the Renaissance. Under the tuition of Thierry of Chartres, in the 1140s, students were taught that the scientific approach was compatible with the story of the Creation in the Bible. In other words, religion was no longer contradicting science. This was a revolutionary new concept and Thierry was incredibly courageous, teaching despite outraged critics. This emerging scientific spirit of Europe found answers in Muslim books which Thierry was ambitious to collect, and his personal library contained many texts translated from Arabic.

These cathedral schools soon gave way to the rise of universities towards the end of the 12th century, although they were not granted recognized charters until the late 13th century.

So the availability of well referenced and researched material kick started European tertiary education. The first university of western Europe was at Salerno in southern Italy, which burst into life in the late 11th century after the arrival of Constantine the African. His rich cargo of books came in Italy from his native Tunisia, and legend has it that he fell into the sea and lost part of his treasure, but what he salvaged, he translated into Latin. These medical books had come from the al Qayrawan Mosque college complex which you can read more about in this chapter in the 'Universities' section. It was these books that triggered the beginning of more advanced medical learning in Europe, because previously Europe had little or no access to research undertaken.

The French city of Montpellier was an offshoot of Salerno and a major centre for the study of Muslim medicine and astronomy. It was



The French cathedral school, Chartres, was one of the leading institutions in the 11th and 12th century. The work done here laid the foundations for the Renaissance.

A dissection lesson at the faculty of medicine in Montpellier University, France from a 14th century French manuscript. Begun in the [illegible] Montpellier was a major [illegible] for the study of Muslim medicine and astronomy.

close to Muslim Spain, with its large presence of learned Muslims and Jews. Montpellier attracted students from all regions to study as early as 1137. One such student was Robert the Englishman who arrived around 1270 and wrote a treatise on the astrolabe, *De Astrolabio Canones*, and a treatise on the quadrant. Both astrolabe and quadrant were Muslim instruments and you can read more about these in the Universe chapter.

By the beginning of the 12th century the thought powerhouse of the Western world had shifted to Paris, 'a city of teachers', as the knowledge of Arabic works was continuing its journey with roving scholars. The Paris intellectuals were in three great schools: the cathedral of Notre Dame, the canons regular of St Victor, and the abbey of St Genevieve across the river.

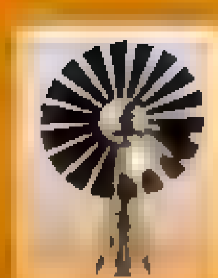
The cathedral school of Notre Dame showed the greatest transformation and by 1170 the university was taking shape as it was fed by the translated, scientific cutting edge material that was filtering north.

Little by little, Parisian masters and students grouped themselves into four faculties: arts, theology, law and medicine. These centres of learning gave birth to Oxford University, partly because Henry II banned English students from attending the University of Paris from 1167 onwards, and partly because Paris was stagnating. Daniel of Morley, a 12th century visiting natural scientist said it was becoming 'stale and moribund' and he moved on to Toledo, the new intellectual epicentre. Daniel himself would return to teach at Oxford, and would certainly supply it with its first books of science, which of course he had imported from Toledo.

Many historians today say that the blueprints of the earliest English universities, like Oxford, came with these travelling, open-minded scholars and returning crusaders who, as well as visiting Muslim universities in places like Cordoba, brought back the translated books based on rational thought and not prophecy.

Right: Notre Dame Cathedral, one of three great schools in Paris that received and transmitted Muslim science

03 MARKET



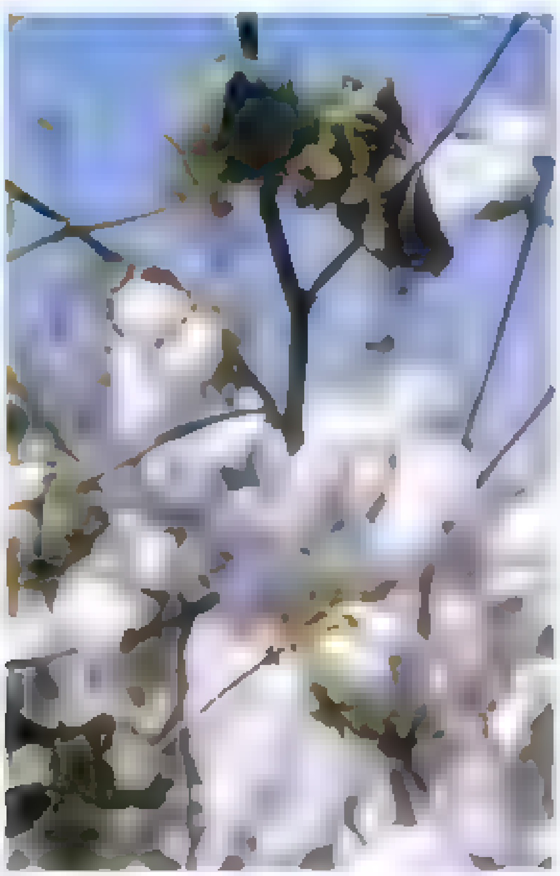
Agricultural Revolution

TODAY, we are more detached from our food sources than we were a thousand years ago. Few of us work the land or raise our own animals. We visit the local shops or supermarket to sample the delights of the world, and can devour mangoes from Pakistan, American strawberries, Dutch mushrooms and beef from New Zealand or Argentina. No longer do we have to wait for summer apples or rely on pickled vegetables in winter; instead we just move along to the next shelf. But this concept of global food, not linked to local seasons and climates, is not new. What is new is that it is flown in, and not grown on our doorsteps.

'It is a blessed act to plant a tree even if it be the day the world ends'

Prophet Mohammed (pbuh) narrated by A. Bukhari and Ahmed

In the 9th century, Muslim farmers were making innovations: introducing new crops from all around the Muslim world; developing intensive irrigation systems, using global knowledge for local conditions in a scientific way, and promoting practical farming that included individual land ownership. This all meant they could have a diversity of food previously unavailable.



Cotton, originally from India, was introduced as a major crop in Sicily and al-Andalus.

The success of their farming also came from hard work. With their love of the land, no natural obstacle could stop Muslim farmers: they tunnelled through the mountains, their aqueducts went through deep ravines, and they levelled the rocky slopes of the Spanish sierra with infinite patience and labour.

Global Knowledge and Scientific Methods

Being from a civilization of travellers, Muslims combed the known world for knowledge and information, journeying in the harshest of environments from the Steppes of Asia to the Pyrenees, detailing all they saw to produce huge agricultural manuals. These were a "spectacular cultural union of scientific knowledge from the past and the present, from the Near East, the Maghrib and Andalusia," said American historian S.P. Scott in 1904.

As Professor Andrew Watson from the University of Toronto says, the Muslim world was "a large unified region which for three or four centuries … was unusually receptive to all that was new. It was also unusually able to

diffuse novelties. ... Attitudes, social structures, institutions, infrastructure, scientific progress and economic development all played a part.... And not only agriculture but also other spheres of the economy – and many areas of life that lay outside the economy – were touched by this capacity to absorb and to transmit.

With this vast array of knowledge coming from a diversity of geographic areas, Muslims could rear the finest horses and sheep, and cultivate the best orchards and vegetable gardens. They knew how to fight insect pests, use fertilizers, and were experts at grafting trees and crossing plants to produce new varieties.

New Crops

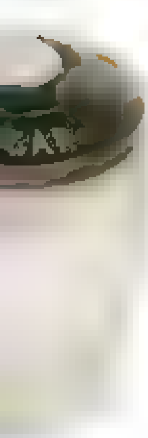
In the ancient Mediterranean world, generally speaking only winter crops were grown, and each field would give one harvest every two years. That was before the Andalusian Muslims arrived with crop rotation techniques as well as new crops, many from India. These needed warm or hot weather, which was provided by the long summer days, although there were also dry months with little rain. With the Muslim introduction of irrigation, though, four harvests each year could now be produced.

Subtropical crops, like bananas, were grown in the coastal parts of the country and the new crops included rice, citrus fruit, peaches, prunes, silk, apricots, cotton, artichokes, aubergines, cotton, saffron and sugar cane. As well as introducing sugar

Some of the crops that the Muslims brought to and cultivated in Europe include (from left to right) citrus fruits, dates and figs.

'The greatest service that can be rendered to any country is to add a useful plant to its culture.'

[illegible]



cane to Spain where it had a huge impact. Muslims also took it into Ethiopia, while also making the East African island of Zanzibar famous for its high quality sugar.

A silk industry flourished, flax was cultivated and linen exported. Esparto grass, which grew wild in the more arid parts of Spain, was collected and turned into products like baskets and floor coverings.

Al-Masudi, a 10th century Muslim traveller and historian, wrote about the introduction of orange and citron trees: "The orange tree, *shajar al-naranj*, and the citron tree, *al-utrujj al-mudawwar*, were brought from India around 300 AH (912 CE) and were first planted in Oman. From here they were carried via al-Basra into Iraq and Syria. In a very short time they became numerous in the houses of the people of Tarsus and other Syrian frontier and coastal towns. Very quickly the trees were sprouting up over Antioch, Palestine and Egypt where but a short time ago they were unknown.'

The transfer of such crops was often due to the enthusiasm of individual people, like 'Abd al-Rahman I who, out of nostalgia for his Syrian landscape, was personally responsible for the introduction of several species, including the date palm, to make himself feel more at home in this new land of al-Andalus or Spain. A variety of pomegranate was introduced from Damascus by the chief judge of Cordoba, Mu'awiya b Salih, and a Jordanian soldier named Safar took a fig cutting and planted it on his estate in the Malaga region. This species, called *safri* after the soldier, spread over the land.

The new crops were also successful because the farmers could identify suitable soil types for each, and had mastered grafting techniques for plants and trees. The farmers also had access to the written works and oral traditions of ancient peoples that had been painstakingly recorded. In addition, exchanges between experts became increasingly frequent, so that in all major towns the libraries were full of works on agriculture.

Irrigation

As we've read, crops were grown in the hot summers, and some of the new crops needed more water than was available, such as sugar cane, which had to be watered every four to eight days. Rice had to be continually submerged. Cotton was grown from the end of the 11th century and, according to the medieval historian Ibn Bassal, had to be watered every two weeks from the time it sprouted until August. The Andalusis were self-sufficient in cotton, and exported to Sijilmasa (Algeria) and as far south as Ifriqiya, Africa. Oranges and other citrus plants were also irrigated, as were many other fruit trees and dry farming crops.

So how were these water demands met? The same way as today, with widespread and

intensive irrigation systems, made not with electric pumps and plastic pipes, but instead with the ingenious apparatuses of their time. Muslims were experts in raising water by several metres, guaranteeing a constant flow by using both pumps and waterwheels or *norias*. In the Valencia area alone around eight thousand *norias* were built to take water to the rice plantations.

Muslims also harnessed animals to power machinery, devised advanced gearing mechanisms, and dug underground canals or *qanats* to take water through harsh, barren deserts, like the Sahara. You can read more about irrigation and water practices in the 'Water Management' and 'Raising Water' sections in this chapter.

For the water to make it to the fields, the level of the irrigation systems had to be correctly calculated, and Muslims had the advantage of the advances they had made in mathematics. By using triangulation they could accurately make measurements of height.

It wasn't only mathematics that helped agriculture, because major advances in astronomy in 11th century Toledo, Spain were also having an impact. As reporter Rageh Omar says in the BBC's *An Islamic History of Europe* '... astronomical tables were used in agriculture ... the tables showed times for planting and harvesting'.

New Landownership Approach

The last important factor for this boom in food production was the development of a new, vigorous system of ownership. Farmers could now work more for themselves and the community, rather than in misery, suffering exploitation at the whim of big landowners. It was a revolutionary social transformation in land ownership when labourers' rights were introduced. Any individual had the right to buy, sell, mortgage, inherit and farm the land, or have it farmed according to his preferences.

Every important transaction concerning agriculture, industry, commerce and employment of a servant involved the signing of a contract and each party keeping a copy. Those who physically worked the land received a reasonable proportion of the fruits of their labours, and detailed records of contracts between landlords and cultivators have survived, showing that the landlord retained anything up to one-half.

With these four major innovations - namely, global and scientific knowledge, new crops, irrigation and land ownership - agricultural development erupted on a scale previously unknown. Before, people lived on a subsistence basis, but now the quality of life increased dramatically, and an enriched diet for all was possible with the introduction of fresh fruit and vegetables. These were available all year round, with less needing to be dried for winter.

Citrus and olive plantations became a common sight, and market gardens and orchards sprang up around every city. All this involved intensive cropping, which could have led to decreased soil fertility, but the technique of intensive irrigation coupled with fertilization techniques, using mainly pigeon dung, had been mastered.

Animal husbandry and selective breeding using animals from different areas meant horse

> **The Spanish Muslims' agricultural system was '... the most complex, the most scientific, the most perfect, ever devised by the ingenuity of man.'**
>
> [illegible]
> American historian
> S P Scott

stocks improved and strong camels could carry the Saharan caravans. Animal manure was available, as well as other animal products like meat, now plentiful in places where in the past it had been a luxury, and wool. The fine quality products from the Maghreb region of Tunisia, Algeria and Morocco soon became known throughout the world.

Not only wool, but now silk and cotton were being produced. Cotton, originally from India, became a major crop in Sicily and al-Andalus, making previously rare luxury goods available. Within a relatively short period, people had access to a wider range of textiles for clothing, which now came in a greater variety of colours.

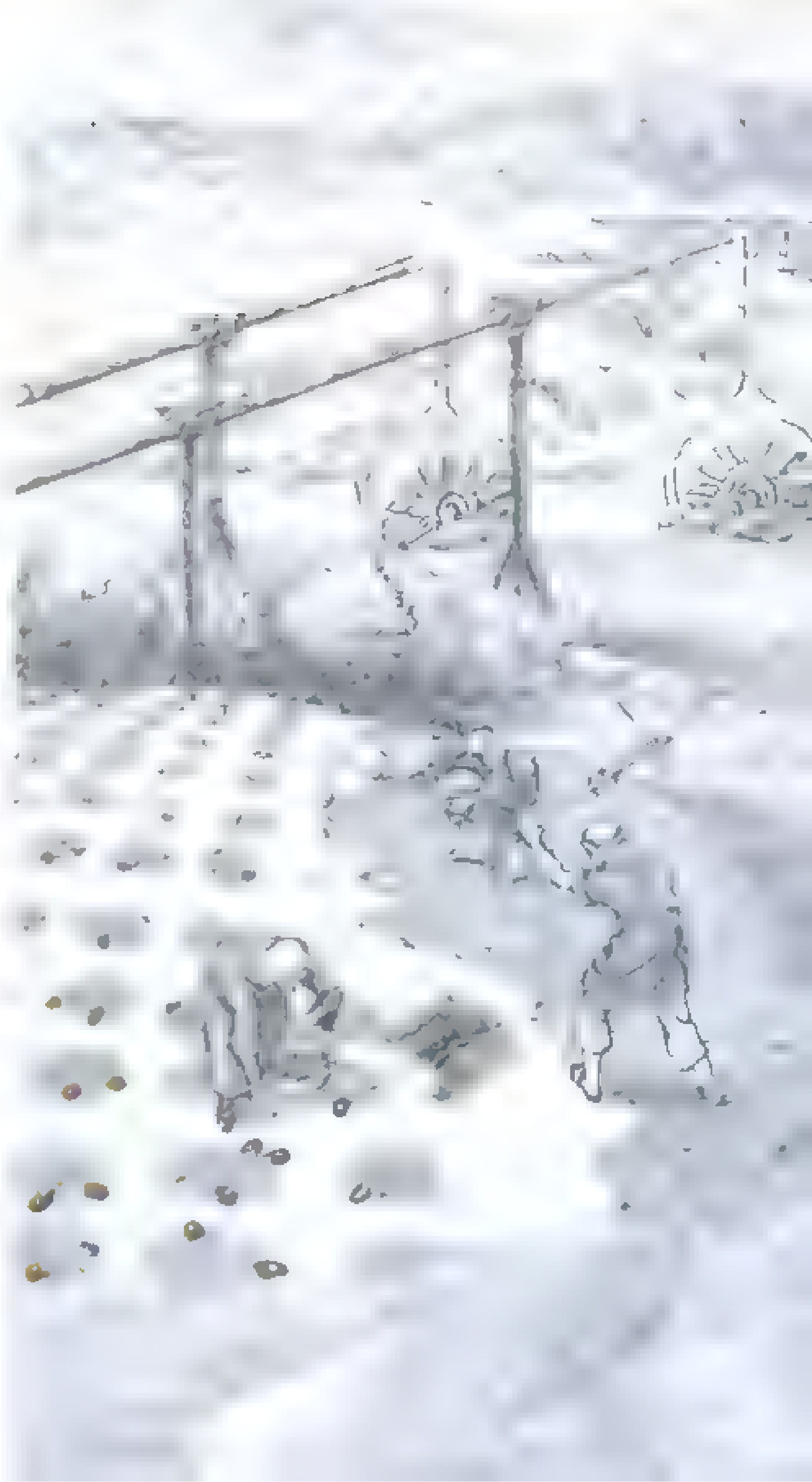
Just as the Muslims of yesteryear wanted their people to have an increased quality of life, so the farmers of today also strive for a similar level of success. They are also searching for concepts to revolutionize 21st century practices to benefit all.

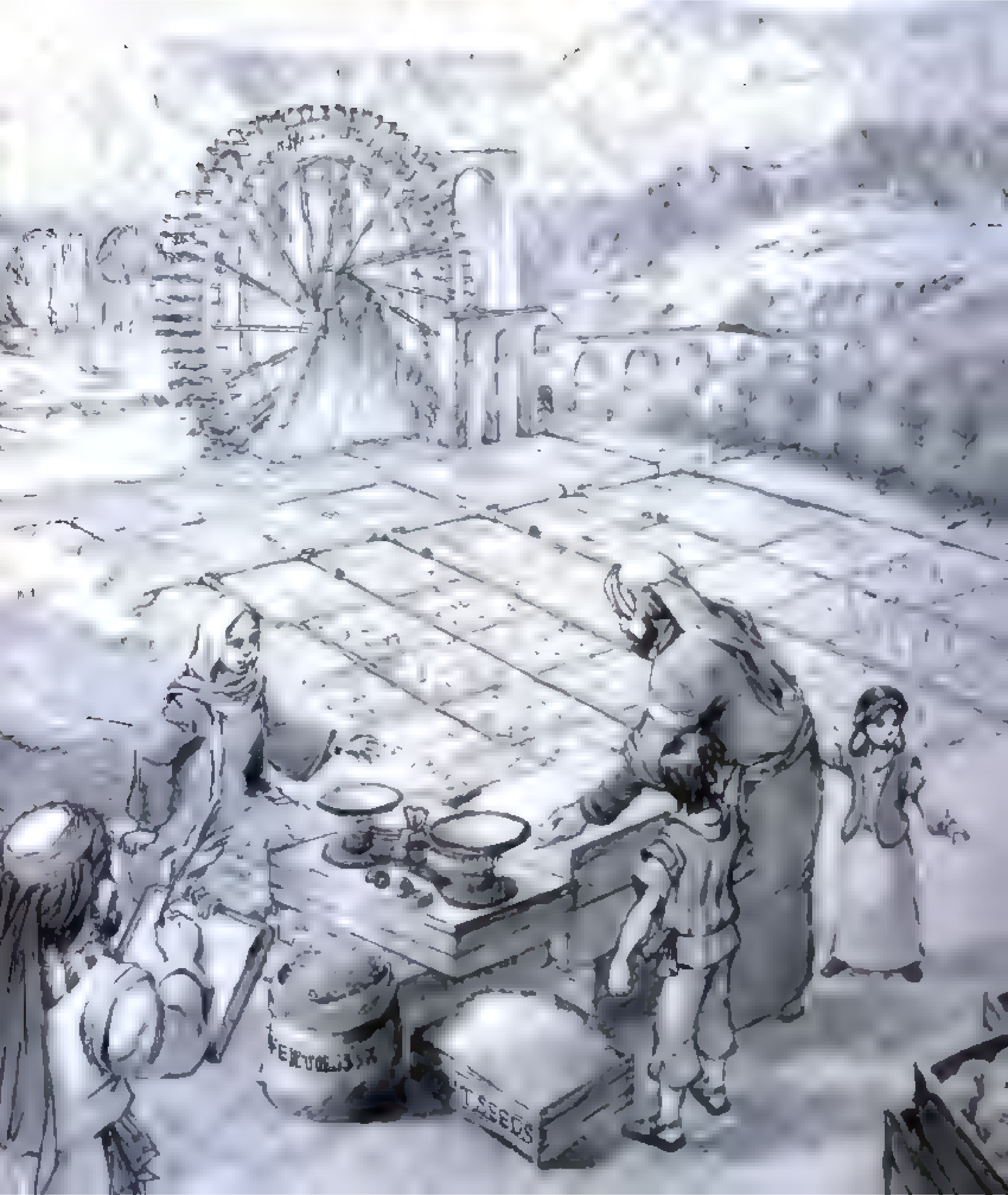
It is admitted with difficulty that a nation of nomads could have known any form of agricultural techniques other than sowing wheat and barley.

The misconceptions come from the rarity of works on the subject. If we took the bother to open up and consult the old manuscripts, so many views will be changed, so many prejudices will be destroyed.

A. Cherbonneau,
19th century French translator and scholar

Innovative Muslim farmers in the 9th century were planting new crops, developing state of the art irrigation techniques, using organic fertilisers, harnessing global knowledge in this area and basing their agronomy on scientific findings. This led to an agricultural revolution, making fresh food available to more people.



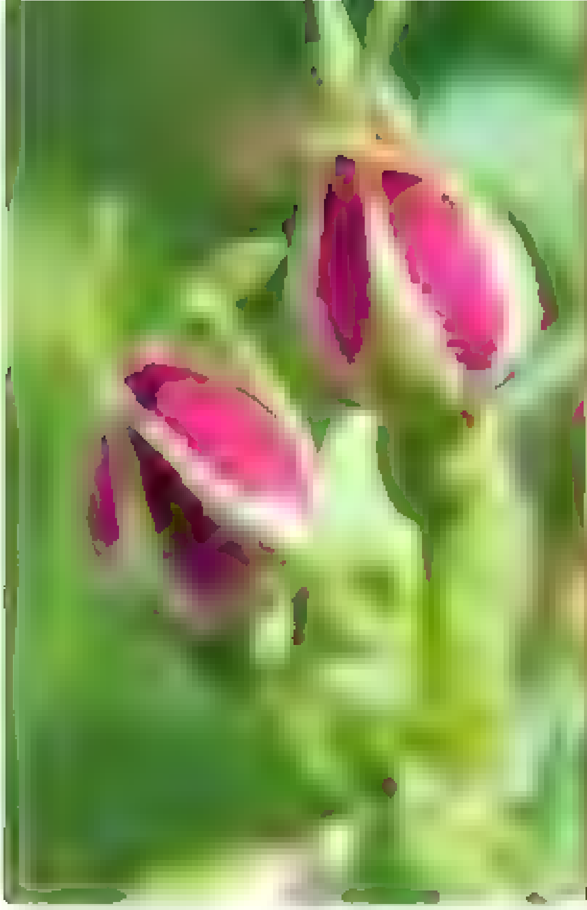


Farming Manuals & Ecological Balance

FOR A GARDEN OR CROP TO BLOOM there has to be an ecological balance between nurture and nature. The elements of soil, water and human intervention have to be in distinctly proportional amounts to ensure a good flowering and harvest. In their bid to achieve maximum output without destroying the things they relied upon, namely the soil and plants, Spanish Muslims started a systematic study of agriculture, including soil chemistry and soil erosion, hundreds of years ago.

Muslim agriculture was a sophisticated affair, which resulted in an ecologically friendly and very productive system. They had farming books that explained just about everything in detail, like how to enrich the soil by ploughing, normal and deep, hoeing, digging and harrowing. Soil was classified, and so was water, according to its quality. Ibn Bassal, gardener to the Emir of Toledo, wrote a *Book of Agriculture* in 1085. This classed ten types of soil, assigning each with different life-sustaining capabilities according to the season of the year. He insisted that fallow land should be ploughed four times between January and May and, in certain cases, like for cotton crops that were planted in heavy Mediterranean coastal soils, he recommended as many as ten ploughings.

14th-century Persian manuscript from Al Biruni's *Chronology of Ancient Nations*



The *Calendar of Cordoba* of 961 had tasks and timetables for each month. March noted that roses came to bud and quails appeared.

Ibn al-Awwam, a 12th century botanist from Seville in Muslim Spain, gathered together previous studies of Greek, Egyptian and Persian scholars into a *Book of Agriculture*, which had thirty-four chapters on agriculture and animal husbandry, while also giving farmers precise instructions. It included 585 plants, explained the cultivation of more than fifty fruit trees, made observations of grafting, soil properties and preparation, manure, plant diseases and their treatments, gardening, irrigation, affinities between trees and beekeeping. It covered all you wanted to know about olives, from how to grow the trees, the treatment of their diseases, grafting, harvesting olives, to the properties of olives, refining olive oil and their conditioning. Then there was a section on ploughing techniques, their frequency, times for sowing and how to sow, watering after sowing and during growth, maintenance of plants, and harvesting. So, with all this information an avid farmer couldn't go wrong, and it was all published in Spanish and French between the end of the 18th and the middle of the 19th centuries.

Then there was the remarkable technical accuracy of the famous *Calendar of Cordoba of 961*. Each month of the year had tasks and timetables: for instance, March was when fig trees were grafted and early cereals began to rise. It was the time to plant sugar cane, and when pre-season roses and lilacs began to bud. Quails appeared, silkworms hatched and mullet began to journey up rivers. This was also the time to plant cucumbers, and sow cotton, saffron and aubergines. During this month mail orders to purchase horses for the government were sent to provincial tax officials. Locusts began to appear and their destruction was ordered. It was the time to plant lime and marjoram and was also the mating season of many birds.

Top right: Sorting rice in Burma. Ibn Bassal focused on rice and described in detail the procedures and methods of growing it back in the [illegible] century.

There was no agricultural stone left unturned; even individual crops were ruthlessly scrutinized. Rice, for example, had Ibn Bassal advising the use of plots that face the rising sun, then the thorough preparation of the soil by adding manure was recommended. Sowing was advised between February and March. Ibn al-'Awwam gave the specific amount of rice that needed to be sown on any given surface and how that should be carried out. He also spoke at length of the watering process specifying that land should be submerged with water up to a given height before the rice was planted. Once the soil had absorbed the water the seeds were covered with earth, and the land submerged with water again.

Rice experts also focused on fighting parasites, clearing weeds, and ways of harvesting, and safe storage. The use of rice as a food took many forms, and Ibn al-'Awwam specified that the best way to cook and eat rice was with butter, oil, fat and milk. An anonymous author of the Almohad dynasty also wrote a recipe book called *The Cookery Book of Maghrib and Andalusia*, which included many recipes, five of them with rice, all sounding most appetizing.

A very important part of farming was ensuring field fertility to achieve a perfect balance. This was thoroughly explored, and a [illegible] has not changed much in a thousand years as medieval Muslims were also liberally applying manure to their fields. Ibn al-'Awwam states that the best manure is from pigeons and by today's standards it was definitely environmentally friendly and organic.

Top left: Ruins of a pigeon tower near Isfahan, Iran. It was believed that the best organic fertilizer was manure from pigeon droppings, and Muslims used it liberally on their fields. The pigeons were actually bred mainly to be used in the postal network for carrying messages.

Pigeon dung was used extensively in Iran, and dotted across the land were pigeon keeps – large circular towers made from mud-brick, with smaller turrets projecting from their summits. A foreigner travelling through the landscape might quite innocently mistake them for fortress homes of some wealthy land barons, as these towers stood at sixty to seventy feet in total height. These pigeon towers were constructed for collecting manure and breeding more pigeons.

Inside, the towers were made up of small cell-like compartments, like a honeycomb. The guano or dung accumulating over time would then be spread on the surrounding fields after the pigeon towers were cleaned once a year. It is said that at one time there were as many as three thousand of these pigeon towers outside Isfahan in Iran, collecting the manure from thousands and thousands of pigeons. Now only the ruins of these towers can be seen, bearing testimony to the glorious past of this time.

'With a deep love for nature, **and a relaxed way of life, classical Islamic society** achieved ecological balance, a successful average economy **of operation, based ... on** the acquired knowledge of many civilized traditions. A **culmination more subtle** than a simple accumulation of techniques, it has been an enduring ecological success, **proven by the course of human history.'**

Lucie Bolens, author of *The Use of Plants for Dyeing and Clothing*

Water Management

WHETHER IT'S ANDALUSIA OR AFGHANISTAN, Chicago or Cairo, water is essential for agriculture, sustenance and is the source of all life. Over four hundred million acres of land are irrigated in the world today and each human should drink two litres daily to stay healthy.

Muslims inherited existing techniques of irrigation, preserving some while modifying, improving and constructing others, and you can read about all this in the next sections. Their engineering advances were partly down to progress in mathematics, which meant hydrology and the machinery for building irrigation devices were constantly being revolutionized. Eleventh-century Persian mathematician and engineer Muhammad al-Karaji talked about "... the bringing to the surface of hidden waters ..." He also covered surveying instruments, methods of detecting sources of water and instructions for the excavation of underground conduits.

These underground conduits or tunnels were dug to prevent water loss by evaporation. Called *qanats*, the oldest were in Persia and with the development of agriculture, and with more crops being planted, they became essential and *qanat* building became a necessity, especially in the dry environment of the Middle East. Later they came to Cordoba, Spain, making water available for urban domestic use.

Persia and today's Afghanistan had hundreds and thousands of wells, all connected by these underground canals. They were constructed to withstand problems of silting and roof cavings, ensuring a continuous flow of water through miles and miles of formidable deserts and hostile terrain. In some areas of solid rock the *qanat* appeared as an overland stream, and then disappeared again as the geology changed. In the Algerian Sahara, there were

'Do not withhold the superfluous water, for that will prevent people from grazing their cattle.'

Prophet Mohammad (pbuh) narrated by Abu Huraira (Vol. 3 No. 543)

Muslims were able to transport water over very long distances using a series of L-shaped wells connected to each other, forming an underground tunnel, called a *qanat* (these are near Isfahan, Iran). They had manhole covers for air circulation, and these helped the flow of the water through the tunnel. Qanats are

also networks of underground tunnels, called *foggaras*. Here farmers also used a water clock, a clepsydra, to control water use for everyone in the area as it timed, night and day, the amount going to each farmer.

In parts of Iran, despite the existence hydro-electric dams and modern irrigation systems, *qanats* are still a farmer's lifeline. Northeast of Shiraz, the precious commodity of water is still obtained from wells supplied by underground canals.

Given the scarcity of water in these hot, arid environments, it had to be controlled and regulated, just as it is today. The authorities of the time played a crucial role too. In Iraq, hydraulic works of a vast nature, like dams, were left to the state, while the local population focussed its efforts on lesser ones, like local water raising machines.

In Egypt, the management of the Nile waters was crucial to every single aspect of life. Both al-Nuwayri and al-Maqrizi, early Egyptian 14th-century historians, stressed the role of dam and waterway maintenance of the Nile. It was the responsibility of both sultans and large land holders, under both Ayyubids and Mamluks, to dig and clean canals and maintain dams. As in Iraq, the sultan took over the larger structures and the people the lesser ones. Most distinguished amirs and officials were made chief supervisors of such works. Under the Mamluks there was even an officer called the *Kashif al-Jusur* whose job was to inspect dams for each province of Egypt.

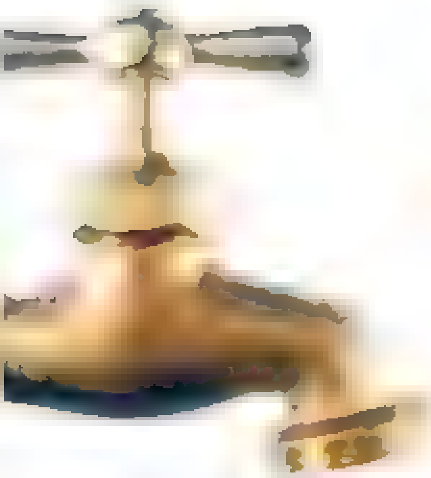
Water was not to be dripped away and was regulated by stringent rules. Waste was banned and in Spain, water was taken from one canal to the other to be used more than once. All disputes and violations of the water laws were dealt with by a court whose judges were chosen by the farmers themselves. This court was called "The Tribunal of the Waters," which sat on Thursdays at the door of the principal mosque. Ten centuries later, the same tribunal still sits in Valencia but now at the door of the cathedral.

Ibn al-Awwam, a 12th century botanist, refers to a drip irrigation technique in his *Book of Agriculture*, saying that it conserves water and prevents over-watering of some species. He partially buried water-filled pots at the base of trees, with specific sized holes for controlling the dripping rate. This technique is widely used around the world now.

As Muslims were accomplished civil and mechanical engineers, nothing came in the way of their extracting water. Even if the water source was in a gorge, the use of sophisticated machinery like water raising machines and pumps revolutionized the society. You can carry on reading more about these these dams and irrigation techniques in the coming sections, and discover the beginnings of water on tap!

The nilometer on Rawda Island at Fustat near Cairo, completed in 861–862 CE. The octagonal column in the centre is used to measure the height of the water in the Nile in cubits.

'There is no life without water.'



Raising Water

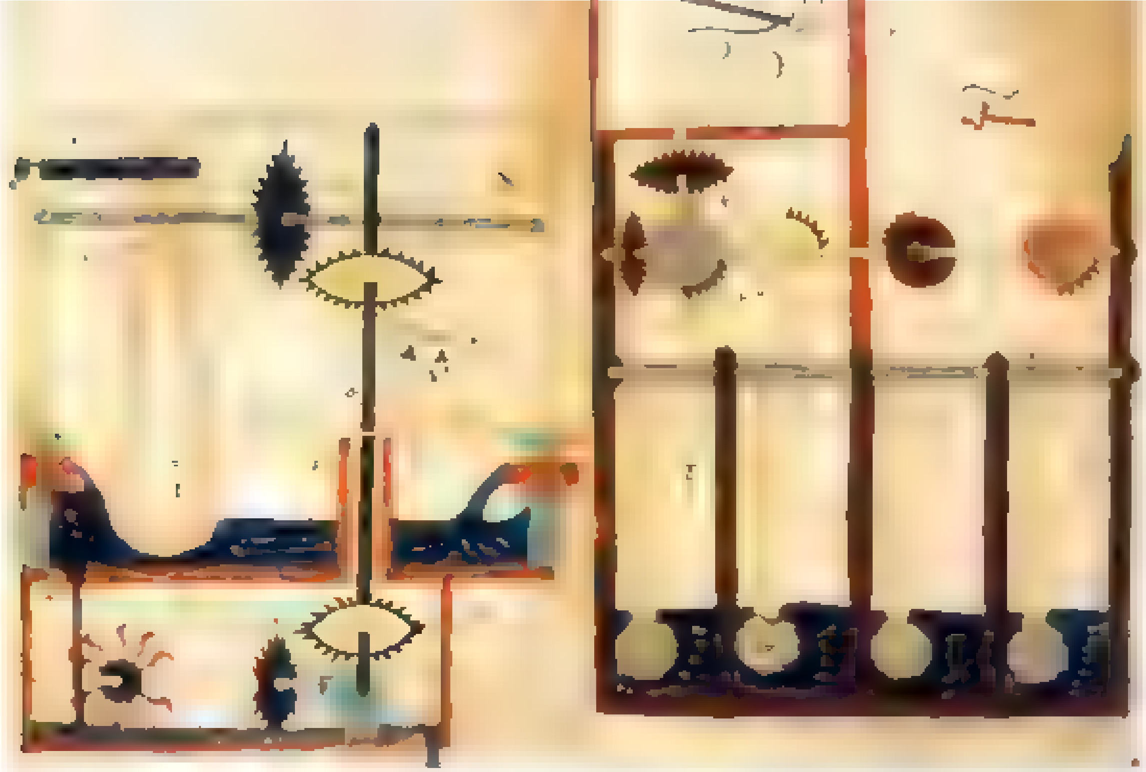
IMAGINE YOUR LIFE TODAY WITHOUT RUNNING WATER, where you have to walk for miles to a river or well and then contemplate how to get it into your bucket as you couldn't get near the fast flow. This was the situation for Muslims before their groundbreaking inventions of water raising machines and pumps, introduced about eight hundred years ago.

They devised new techniques to catch, channel, store and lift the water, and made ingenious combinations of available devices, drawing on their own knowledge and that of other civilizations.

The ancient Egyptians already had the *shaduf*, a simple but effective contraption that took water from the river in a bucket tied to a long, pivoted pole. The bucket had a counterweight, and it was all supported between two pillars on a wooden horizontal bar. It is still used in Egypt today.

Large waterwheels, or *norias*, have raised water from fast flowing waterways to higher land since 100 BCE. Vitruvius, the Roman writer, architect and engineer mentioned this simple, yet powerful device. Like any waterwheel, it was turned by the force of flowing water against paddle compartments on its rim. These filled with water and took it to the top, where they emptied into a head tank connected to an aqueduct. Already used by the Romans and Persians, they were adapted and redeveloped by the Muslims.

Left to right: A noria in Hama, Syria on the Orontes River; engraving showing the [illegible] in Egypt an shaduf [illegible] irrigation.



Left to [illegible] 13th century [illegible] water rais-ing machines designed by al-Jazari. The water raising machine is driven by a water turbine through geared shafts which turn a scoop wheel carrying a long belt of buckets. Al-Jazari made a wooden animal and placed it on the rotating disk, so that people did not think this an [illegible]. They thought it was [illegible] gears with partial teeth to produce a sequence of motion in four scoops that took water from the river one scoop at a time. [illegible] added the [illegible] appearance of a camshaft which controlled the mechanism.

The first Muslim mention of *norias* refers to the excavation of a canal in the Basra region in the late 7th century. The wheels at Hama, on the river Orontes in Syria, still exist, although they are no longer in use. They were big wheels and the largest was about twenty metres in diameter, with its rim being divided into 120 compartments. The *noria* at Murcia in Spain, La Nora, is still in operation, although the original wheel has been replaced by a steel one. Apart from this, the Moorish system is otherwise virtually unchanged. There are still lots of *norias* in various parts of the world, and they are often able to compete successfully with modern pumps.

Many Muslim technologists recognized that harnessing power from both water and animals could increase the amount of work done. Two great innovators and Muslim engineers were al-Jazari and Taqi al-Din. Both carried out a number of experiments building remarkable machines that have led to automated machinery, which has made such an enormous impact on civilization today.

Al-Jazari lived in South West Turkey in the late 12th and early 13th centuries, and was employed by the Artuqid king of Diyarbakir around 1180. He was fascinated by the improvement and development of mechanical devices, just like modern day engineers who seek optimization as a key aspect in improving performance. When you've finished reading about his water raising machines, go to 'Clocks' in the Home chapter to find out about his timekeeping devices.

As a skilled draftsman, he came up with an ingenious device for lifting huge amounts of water without lifting a finger, being the first person to use the crank in his crank-connecting rod system. The crank is considered one of the most important mechanical discoveries made, because it translates rotary motion into linear motion. Today, cranks are in all kinds of things from toys to serious machinery like car engines and locomotives.

Al-Jazari used a machine powered by an animal with a flume-beam, which was moved up and down by an intricate system involving gears and a crank known as a slider crank mechanism. The crank, as part of a machine, didn't appear in Europe until the 15th century when it started a revolution in engineering.

'It is impossible to over emphasize the importance of al-Jazari's work in the history of engineering. It provides a wealth of instructions for design, manufacture and assembly of machines.'

British chartered engineer Donald Hill

Left to right: 3-D rendering of al-Jazari's reciprocating pump; manuscript showing al-Jazari's reciprocating pump. See the crank where the circular motion of the gear in the centre is converted into a linear motion to drive the two pistons. This is the first time a crank appears in manuscripts. The piston movement (opposite page) causes the water to be pulled into the piston chamber, and then pushed into the outlet pipe.

> ... We made from water every living thing....
>
> Q[illegible]

Al-Jazari's Reciprocating Pump

Al-Jazari designed five water-raising machines. Two of them were improvements on the *shadoof*, and one replaced animal power with gears and water power. After the introduction of the crank shaft, his other radical breakthrough came when he made a water-driven pump. This involved cogwheels, copper pistons, suction and delivery pipes, and one-way clack valves. The pump sucked water, to be used in irrigation and sanitation, up twelve metres into the supply system. It is a very early example of the double-acting principle of one piston sucking while the other delivers, and al-Jazari perfected the seals on the pistons and the one-way valve to make it all work.

If you ever felt like making your own 13th-century water-raising machine with reciprocating pump, here are details of how it worked.

Similar to a water mill, it would be built next to a flowing river with half of its paddle in the forceful current. This paddle wheel drove an internal gearing mechanism, powering pistons which moved with the motion of the lever arm, and a reciprocating pump was created.

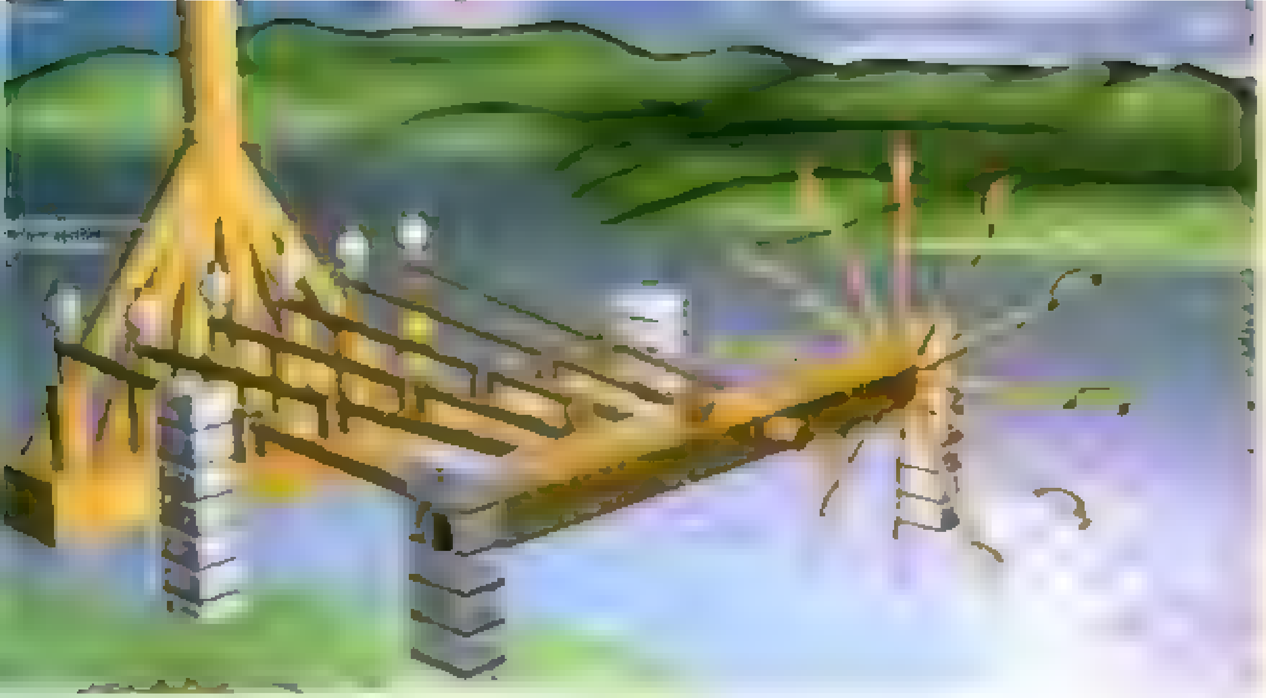
Clack valves helped to draw and expel the water through the pipes. The inlet pipe was submerged in water, and when the piston was pulled along the length of its cylinder, water would be sucked in through the inlet valve. The outlet valve remained closed during this time, because of gravity and the position of its pivot point.

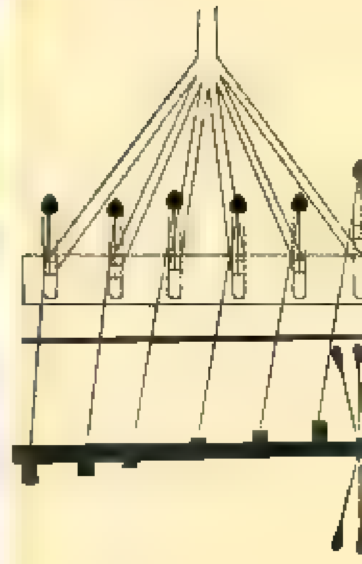
When the piston was on its push stroke, the water in the cylinder was forced through the outlet valve and through an outlet pipe that was narrower than the inlet pipe. The inlet valve remained closed during this time because of gravity and the position of its pivot point.

This motion was alternated between either side of the device, and so when one side was on its push stroke, the other was on its pull stroke. Therefore two 'quantities' of water were being raised per one complete revolution of the waterwheel, and this carried on as long as there was flowing water to drive it.


Inlet clack valve open
Water being drawn into inlet pipe


Outlet clack valve open
Inlet pipe





Above: Taqi al-Din's six-cylinder water pump. Note the cam shaft controlling the motion of the connecting rods to produce a progressive motion of the six pistons so that water is raised continuously.

Opposite page top: A view of camshaft and waterwheel.

Opposite page bottom: A view of pistons and cylinder block.

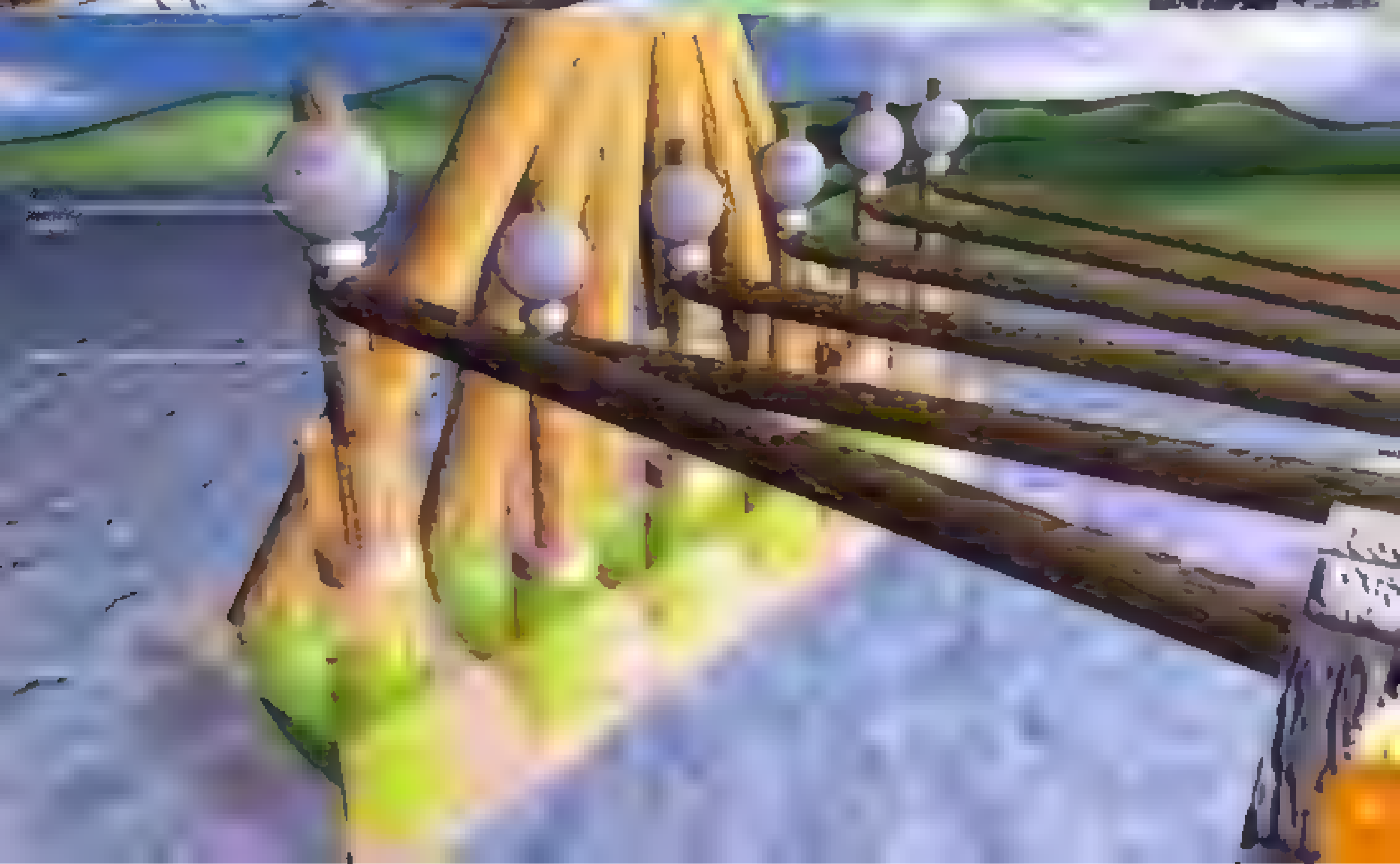
Taqi al-Din's Six-Cylinder Pump

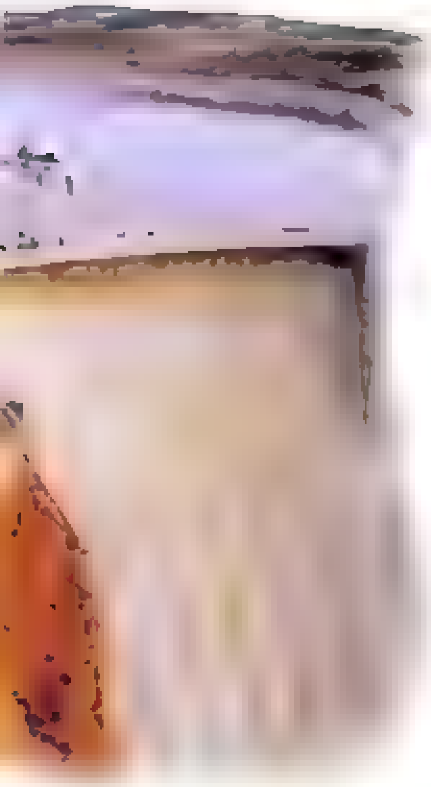
The other technological whiz was 16th-century Ottoman engineer Taqi al-Din al-Rasid, who wrote a book on mechanical engineering called *The Sublime Methods of Spiritual Machines*. As well as talking about water pumps he also discussed the workings of a rudimentary steam engine, about a hundred years before the 'discovery' of steam power.

His six-cylinder pump and water-raising machine forms part of the study of the history of papermaking and metal works, as the pistons were similar to drop hammers, and they could have been used to either create wood pulp for paper or to beat long strips of metal in a single pass.

Taqi al-Din explained how the pump worked in his manuscript. The six-cylinder pump had a waterwheel attached to a long horizontal axle, or camshaft, which had six cams spaced along its length. The river drove the waterwheel, which rotated and turned the camshaft. Each cam on the camshaft pushed a connecting rod downwards, and all connecting rods were pivoted at the centre. At the other end of the connecting rod was a lead weight which lifted upwards and pulled a piston up with it. Now a vacuum was created, and water was sucked through a non-return clack valve into a piston cylinder. After the camshaft had rotated through a certain angle, the cam released the connecting rod and the piston's stroke ended. Through gravity, the lead weight pushed the piston down, forcing water against the clack valve, but the clack valve closed, so the water had to go through another hole and into the delivery pipes. The beauty of the mechanism was in the synchronization and control sequence of all the pistons, which was provided by the angular arrangement of the cams around the shaft.

In a time before a dependence on machinery, when we weren't surrounded by cars, bicycles, or electric pumps, these discoveries really changed society. These machines would not be mass manufactured in factories, but many towns would have a water pump and life, for some, was made immeasurably easier. No longer were people heaving water containers around, or waiting their turn to use the *shadoof*. Instead they stood by pumps or aqueducts, waiting to catch some of the precious liquid gathered by their water wheels, just as we today wait a split second for the water to flow from our taps.





Dams

Dams are some of the largest civil engineering structures ever built and they play a vital role in civilization. Without dams, more floods would ravage lands, irrigation wouldn't have been as large scale, and we wouldn't have hydroelectric plants pumping out power today. Without dams and their reservoirs, life as we know it wouldn't be the same because of the major impact they have had on economic and social life.

For thousands of years, engineers have been trying to control water with various types of dams that have to hold back raging torrents and provide water in dry spells. There are arch dams, buttress dams, embankment dams, to name just a few, and where to put which depends on factors such as the shape of the valley and the bedrock of the river. These considerations are nothing new, as Muslims built many dams in a rich variety of structures and forms centuries ago.

From studying the river, its flow and surrounding topography, these medieval engineers decided whether a dam should be arched or straight, thick or thin, or have deep or shallow foundations, as all these considerations influenced the selection of the most efficient water storage design.

The design and aesthetics of the most impressive of these dams were produced by the Aghlabids of Tunisia near their capital, al-Qayrawan, in the 9th century. Their remains are still preserved, attracting the curiosity of thousands of tourists today. Al-Bakri, an 11th-century geographer and historian from southern Spain wrote about one of them. He said it "...is circular in form and of enormous size. In the centre rises an octagonal tower covered by a pavilion with four doors. A long series of arcades of arches resting one upon the other ends on the south side of the reservoir."

The reservoir on the wadi Marj al-Lil near al-Qayrawan in Tunisia, built by the Aghlabids in the 9th century, is one of the oldest surviving reservoirs in the Muslim world.

Craig Goch Dam, Elan Valley, Wales, UK

In this region of Tunisia, there were over 250 reservoirs, with two basins each. One was used for decantation, the separating the sediment from the water, and the other was a reserve. Sometimes, on the larger schemes, there was a third one for drawing water.

In Iran is the Kebar dam, the oldest arched dam known, which is about seven hundred years old. This dam, like many of its design, had a core of rubble masonry set in mortar. The mortar was made from lime crushed with the ash of a local desert plant, making it strong, hard and impervious to cracking. Then there was the impressively curved Qusaybah dam, which was thirty metres high and 205 metres long. It was built near Medina, now in Saudi Arabia.

In today's Afghanistan, three dams were completed by King Mahmoud of Ghaznah in the 11th century near his capital city. One, named after him, was located a hundred kilometres south west of Kabul. It was thirty two metres high and 220 metres long.

Half of the dams constructed had a flood overflows at one end, and many had a downstream training wall to guide the spilt water to a safe distance from the dam's foot.

Dam construction in Muslim Spain was immense, and the masonry they used was a type of cement that was harder than stone itself, so they needed hardly any repairs in a thousand years. Each of the eight dams on the Turia River have foundations that go fifteen feet into the river bed, with further support provided by rows of wooden piles. The solid foundation was needed due to the river's erratic behaviour: in times of flooding its flow was a hundred times greater than normal. The dams had to be able to resist the battering of water, stones, rocks and trees, which they did, and now, over ten centuries later, they still continue to meet the irrigation needs of Valencia, requiring no addition to the system.

The dam on the River Segura, in the Murcia region of Spain, shows how the Muslims understood that location and the nature of

In Iran is the Kebar dam, the oldest arched dam known and about seven hundred years old.

Khaju Bridge, also a dam on the River Zayandeh in Isfahan, Iran was built in the mid 17th century by Shah Abbas II of the Safavid dynasty. The bridge was set on a stone platform and divided by sluices which regulated the flow of the river.

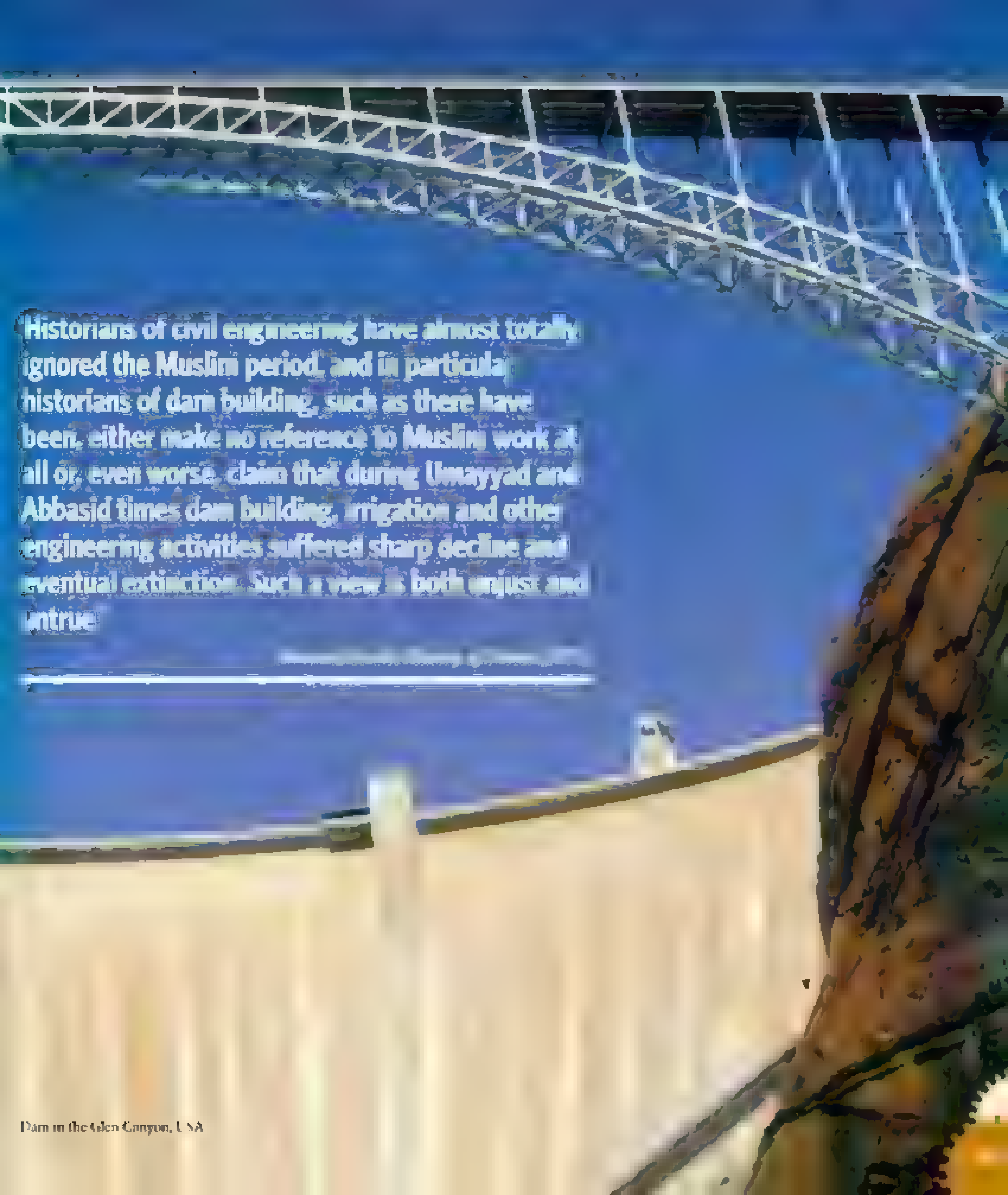
the local environment mattered. The height of this dam was only twenty-five feet, but the thickness of its base was between 150 and 125 feet. This was necessary because of the softness and weakness of the river's bed, and its design prevented the dam from sliding along. The water flowing over the crest initially fell vertically through a height of thirteen to seventeen feet onto a level platform, and then ran the length of the dam. This dissipated the energy of the water spilling over the crest. The overflow then ran to the foot of the dam over flat or gently sloping sections of its face. In this way the whole dam acted as a spillway, which reduced the risk of disturbing the downstream foundations.

The city of Cordoba, on the river Guadalquivir probably has the oldest surviving Islamic dam in the country. According to the 12th-century geographer al-Idrisi, it was built of qibtiyya stone and included marble pillars. The dam follows a zigzag course across the river, a shape which shows that the builders were aiming at a long crest in order to increase its overflow capacity. Remains of the dam can still be seen today, a few feet above the river bed, although in its prime, it would have been about seven or eight feet above high water level and eight feet thick.

To build such immense structures, Muslim engineers used sophisticated land surveying methods and instruments, like astrolabes and also trigonometric calculations. They found the most suitable sites for the dams, and they could also lay out complex canal systems. Around Baghdad, water was diverted into the Nahrwan canal, which was used for irrigation.

Dams were built of carefully cut stone blocks, joined together by iron dowels, whilst the holes in which the dowels fitted were filled by pouring in molten lead. The level of craftsmanship and superiority of design attained means that a third of all 7th- and 8th-century dams are still intact. The other two-thirds were destroyed by centuries of warfare, from the armies of Genghis Khan and the Mongols to Timur's hordes. These conflicts laid waste many irrigation works and the ones that survived did so because of their brilliant construction, and because they were out of reach.

Muslims were also investing in 'green energy' when they used stored water for mill power. In Khuzistan, at the Pul-i-Bulaiti dam on the Ab-i-Gargar, the mills were installed in tunnels cut through the rock on each side of the channel, constituting one of the earliest examples of a hydropower dam, and it was not the only one in the Muslim world. Another example was the bridge-dam at Dizful, which was used to provide power to operate a *noria*, a huge waterwheel, which was fifty cubits in diameter, and supplied water to all the houses of the town. Many such hydraulic works can still be seen today.



"Historians of civil engineering have almost totally ignored the Muslim period, and in particular historians of dam building, such as there have been, either make no reference to Muslim work at all or, even worse, claim that during Umayyad and Abbasid times dam building, irrigation and other engineering activities suffered sharp decline and eventual extinction. Such a view is both unjust and untrue"

Dam in the Glen Canyon, USA

Windmills

TO PRODUCE ANYTHING, energy is needed, and before oil powered machines, energy came from sustainable sources. Some energy in the Islamic world over a thousand years ago came from water, and was harnessed in machines like the crank-rod system which took water to higher levels and into aqueducts to quench the thirst of towns. Water drove mills to grind wheat, but in drier parts of the Islamic world there was not enough water, so alternative power supplies were sought.

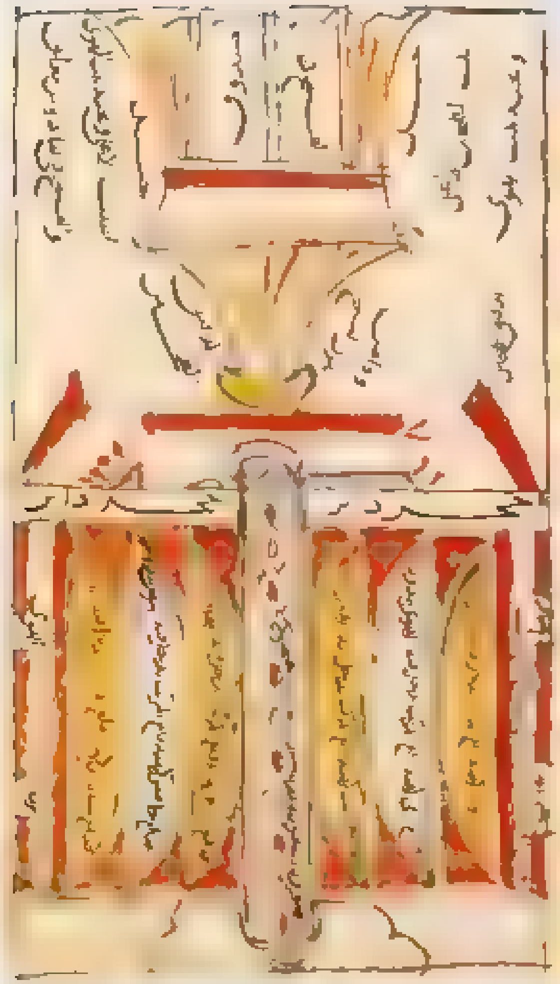
One thing the vast deserts of Arabia had when the seasonal streams ran dry was wind, and these desert winds had a constant direction. So for about one hundred and twenty days the wind blew regularly from the same place. The windmill was so simple, yet effective that it quickly spread all over the world from its 7^{th} century Persian origins. Most historians believe that it was the crusaders who introduced windmills to Europe in the 12^{th} century.

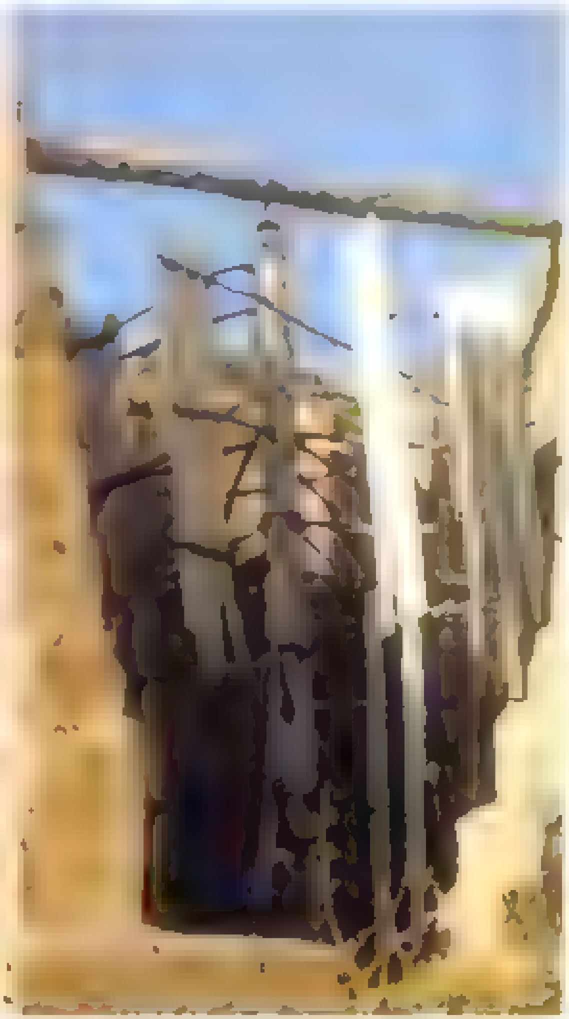
A Persian had come to the second Caliph Umar, who reigned for ten years from 634 CE, and claimed he could build a mill operated by wind, so the Caliph ordered him to have one built. After this, wind power became widely used to run millstones for grinding corn, and also to draw up water for irrigation. This was done first in the Persian province of Sistan, and al-Masudi, an Arab geographer who lived in the 10^{th} century, described the region as a 'country of wind and sand.' He also wrote: 'a characteristic of the area is that the power of the wind is used to drive pumps for watering gardens.'

Early windmills were two-storey buildings and were built on the towers of castles, hill tops or their own platforms. On the upper storey

Attempts to use environmentally friendly energy have revived the call for the use of wind power.

Left to right: [illegible] manuscript by al-Dimashqi showing the [illegible] mill whose vertical vanes rot[illegible] an old windmill in [illegible], Afghanistan.





were the millstones, and in the lower one was a wheel, driven by the six or twelve sails that were covered with fabric. These turned the upper millstone. These lower chamber walls were pierced by four vents, with the narrower end towards the interior, which directed the wind onto the sails and increased its speed.

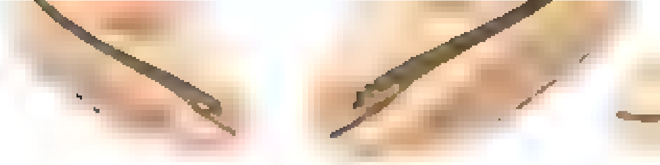
Windmills from that time were described as containing a millstone attached to the end of a wooden cylinder. This was half a metre wide, and three and a half to four metres high, standing vertically in a tower open on the northeast side to catch the wind blowing from this direction. The cylinder had sails made of bundles of bush or palm leaves, attached to the shaft of the axle. The wind, blowing into the tower, pushed the sails and turned the shaft and millstone.

The introduction of the windmill and watermill had a great effect on the science of mechanical engineering and meant that new trades were born, from the actual building of mills to their maintenance. This job was normally carried out by the miller and his apprentices, and they were the predecessors of today's mechanical engineers.

'Behold!
a giant am I!
Aloft here in
my tower,
With my
granite jaws I
devour
The maize, and
the wheat, and
the rye,
And grind them
into flour.

I look down
over the farms;
In the fields of
grain I see
The harvest
that is to be,
And I fling to
the air my arms,
For I know it is
all for me.'

Excerpt from
The Windmill by
Henry Wadsworth
[illegible]



Trade

CITIES AND TOWNS SWELLED and hummed with transport, barter and selling. Peddlers cried their wares to latticed windows, stock dangled in shops while people haggled, and fairs, markets and bazaars gathered merchandise, merchants, buyers and poets from all over the world.

Trade has a long tradition in Islam and Prophet Mohammad (pbuh), and many of his companions, were tradesmen. Life as a trader and merchant meant travelling and being independent from one's family and local community, so Islam provided a spiritual basis for life in a new travelling dimension. Because it played a major part of Islamic life, trade was governed by a well developed body of legislation covering contracts, exchanges, loans and market conduct.

The vast network of trade stretched its arteries over an empire that coursed with an eclectic collection of merchants and goods. Gold and white gold, as salt was known, travelled north and east from the African Sahara into Morocco, Spain and France, with lesser quantities making their way into Greece, Turkey, Egypt and Syria. Cowrie shells (they were a currency in the 14^{th} century) went from the Maldives to West Africa. Pottery and paper money came west from China but the paper currency didn't catch on in Cairo. Travellers also flowed along with the wool and wax, gold and melons, ivory and silk, sheikhs and sultans, wise men and pilgrims.

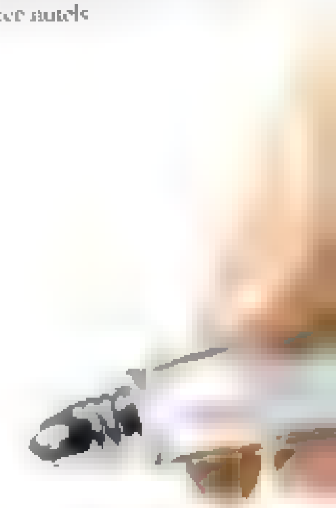
Artistic impression of 14^{th} century souk

Seljuk caravanserai in Konya, Turkey. Caravanserais were charitable foundations and provided facilities, such as food and shelter, to travellers for free. They were the motorway service stations of their time, but these were free hotels.

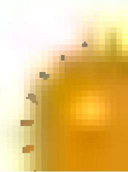
The land trade passing on the Silk Route was the heartbeat of the Muslim economy. The sea trade was mainly along the Mediterranean shores of Africa and Europe. The port of Malaga in southern Spain was a centre of immense traffic, visited by traders from all countries, especially those from the mercantile republics of Italy, like the Genoese. It was in this port that the enterprising Genoese were granted a suburb in their name. Ibn Battuta sailed to Anatalia on a Genoese boat, because they dominated this part of the trade routes, and he said 'The Christians treated us honourably and took no passage money from us'.

The Muslim merchants of the Adriatic took a larger share of world trade at that time and lined the crowded quays of Malaga, flying their eye-catching flags among the ensigns of the maritime nations. A constant passage of vast and growing traffic came through the port of Malaga. Here traders bartered the commodities of every country from silks, weapons, jewellery, and gilded pottery, to the delicious fruits of Spain.

Alexandria was another major port at the mouth of the Nile delta, spilling into the Mediterranean Sea. It was pulsating with life because the Spice Route passed through the city, making it the gateway into Europe for goods coming from the Indian Ocean, through the Red Sea and down the Nile. It had two harbours, a Muslim one in the West and a Christian one in the East, which were separated by the Island of Pharos and its enormous lighthouse, known at this time as a wonder of the world.



One of the key instruments that Muslims developed to help trade was the construction of rest stations like hostels along the road, known as caravanserais. This building type was spread by the Seljuks. Caravanserais were charitable foundations, providing travellers with three days of free shelter, food and, in some cases, entertainment. This was part of the charitable work towards travellers that was and still is emphasized by Islam. Caravanserais were set up at regular intervals of about thirty kilometres along important trade routes. They had a courtyard bordered with *iwans* and, along the walls, rooms were arranged according to their function for lodging, depots, guard rooms or stables. Today's equivalent would be service stations along most European motorways.



Below left to right: Trade routes; scene from a 13th-century miniature showing a bazaar. Textile and ceramics salesmen sell their goods, while a hawker serves customers.

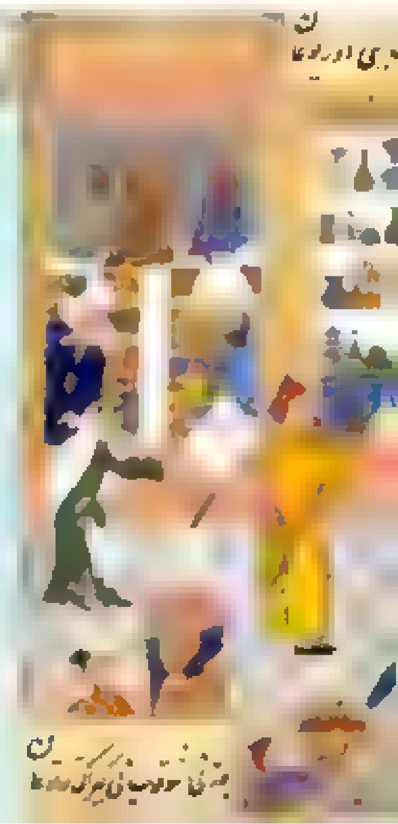
As the merchants carried their wares across the world, they also took Islam with them. Up the Chinese coast in Khanfu, now Canton, a colony of Muslim and Jewish merchants was well established in the 8th century. It was through the honesty and friendliness of these traders that Islam spread to China and Central Africa. Muslim merchants penetrated Africa, and it was initially Berber merchants who carried Islam across the Sahara. All nomads in North East Africa, where trade routes linked the Red Sea with the Nile, quickly became Muslims.

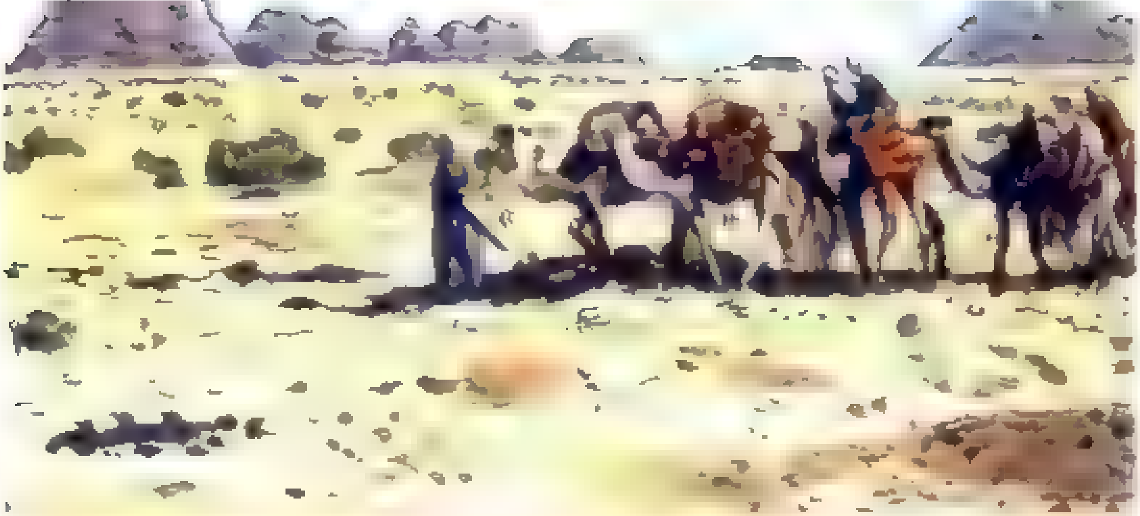
Some centres in the Islamic world constituted thriving communities due to their important place in commercial exchanges. Al-Qayrawan in Tunisia and Sijilmasa in Morocco were described by the 10th-century traveller Ibn Hawqal in his *Book of the Routes of the Kingdoms*. 'Al-Qayrawan, the largest town in the Maghreb, surpasses all others in its commerce, its riches, and the beauty of its bazaars. I heard from Abu al-Hasa, the head of the public treasury that the income of all provinces and localities of the Maghreb was between seven hundred and eight hundred million dinars ... Amongst the exports to the East are amber, silks, suits of very fine woollen fineries, woollen skirts, carpets, iron, lead, mercury... .'

Europe, Asia and Africa imported vast amounts from Islamic lands, including enamelled glassware, tooled leatherwork of all sorts, tiles, pottery, paper, carpets, carved ivories, illustrated manuscripts, metalwork including Damascene swords and vessels, fine cotton cloth and rich silk fabrics.

Muslim textiles, metal and glass pieces were highly prized, as were soaps. Mamluk gilt and enamelled glass, a labour-intensive luxury product made using expensive materials, had a peculiar status. Archaeological finds uncovered Mamluk enamelled glass on the northern shores of the Black Sea, from where they made their way up to Kiev, in today's Ukraine, and then into Byelorussia, Lithuania, and into Muscovy. They have also been found in Scandinavia, the Hanseatic ports, and Maastricht in Holland.

The legacy of this vast trading world can be seen today. As 20th century American historian Will Durant said: 'It left its mark upon many European languages in such words as tariff, traffic, magazine, caravan, and bazaar. The state left industry and commerce free, and aided it with a relatively stable currency.' (The word traffic is derived from the Arabic *taraffaqa* meaning to walk slowly together, and tariff comes from the Arabic word *Ta'rif*, meaning announcement or information.)





[illegible]

Persia, Syria and Egypt

[illegible]

on the march), and horse drawn wagons transporting the people'

[illegible]

glow with light, and turning night into day

'The Arabs, masters of an empire extending from the Gulf of Gascony to beyond the Indus, involved in commercial enterprises reaching into Africa and Baltic Europe, brought East and West together, as never before.'

Robert Lopez
historian of the commercial expansion of the late medieval period

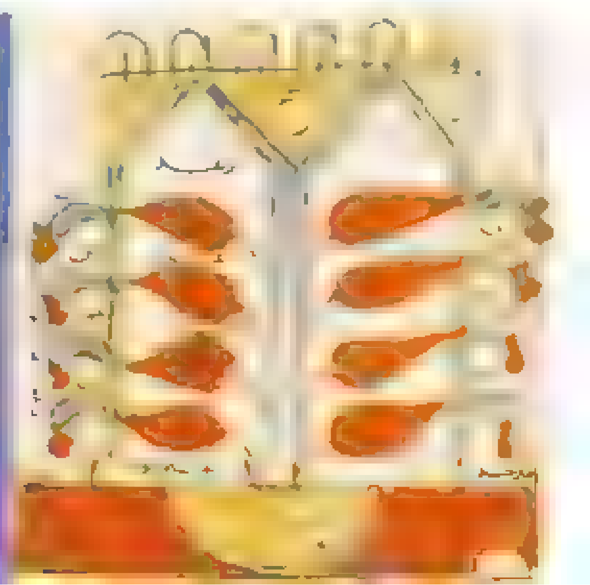
Commercial Chemistry

THE SYSTEMATIC APPROACH of Muslim chemists over eleven hundred years ago led to the discovery of a process that today affects every person and every nation on earth. And a product of this process, after water, is now considered as one of life's biggest essentials. Who would have thought that the black sludge known in Arabic as *naft*, could have over four thousand uses? Without the process of distillation, and in this case of crude oil, we'd have no petrol, kerosene, asphalts or plastics.

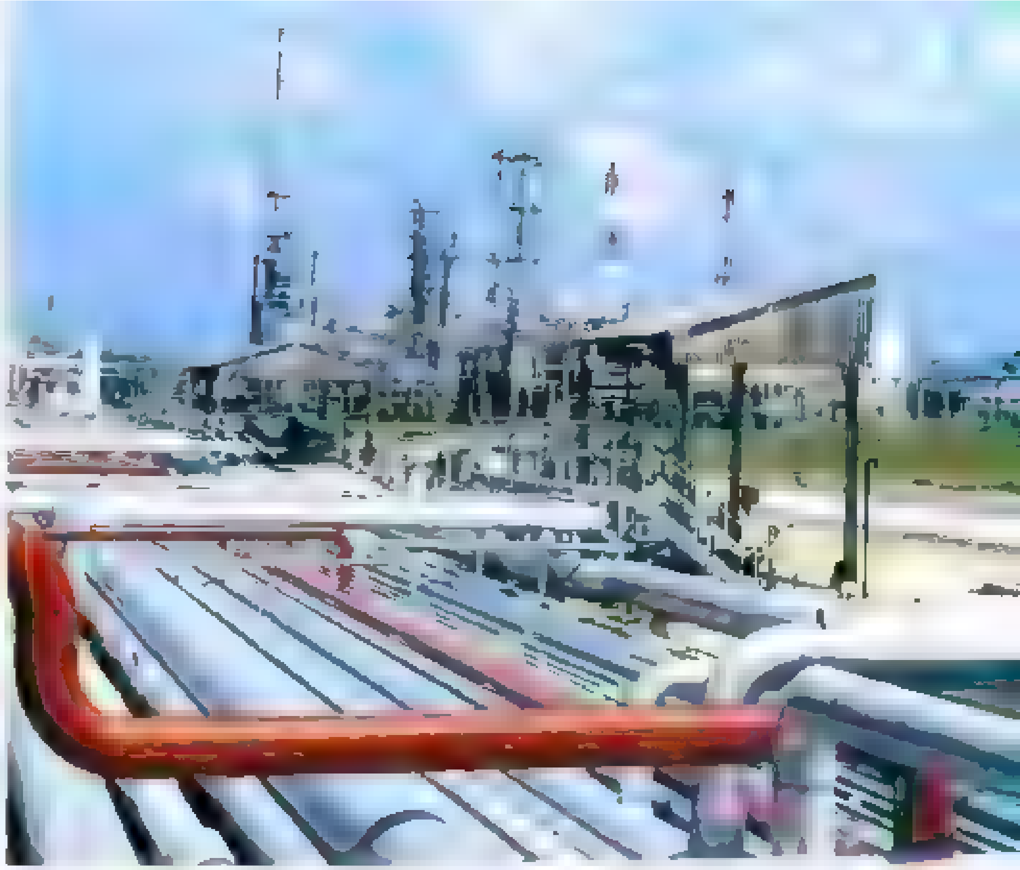
Distillation is a means of separating liquids through differences in their boiling points, and was known to Muslim chemists since the 8th century. Its first and most renowned application was in the production of rose-water and essential oils. Pure alcohol was also obtained from the distillation of wine, which was produced and consumed mainly by non-Muslim communities, like Christians living under the Muslim rule. Jabir ibn Hayyan described a cooling technique that could be applied for its distillation. This distilled alcohol and alcoholic mashes were then used in chemical processes for the production of acids, medicines, perfumes and inks for writing, as Islam prohibits the consumption of alcohol and other toxic drinks.

Jabir was the first to develop the alembic still in the 8th century, which is still used today in distillation laboratories. It cooled and collected the necessary liquids in the distillation process. The word, alembic, like much chemical terminology, comes from the Arabic *al-anbiq* which means 'the head of the still.' The alembic still has two retorts connected by a tube. It was in the alembic still that Jabir observed the flammable vapours coming from boiling wine and salt. In his chemistry book he wrote: 'And fire which burns on the mouths of bottles due to boiled wine and salt, and similar things with nice characteristics, which are thought to be of little use, these are of great significance in these sciences.'

Below left to right: Today's symbol for acids. Many chemical acids were first introduced by Jabir ibn Hayyan; an Islamic alembic apparatus used for distillation in the 10th to 12th centuries; a 14th-century manuscript showing hemispherical vessels with a rose and water mixture resting on a fire (the red base). The vapours are collected and cooled in the eight vessels on either side of the central column; they feed into the eight, external alembics which convey the distilled rosewater into eight external flasks.



A modern day oil refinery in Malaysia



The flammable property of alcohol was used extensively from Jabir's time. There are descriptions in military treatises from the 14th century of distilled old grape wine becoming an important ingredient in the production of military fires. These manuscripts also came with warnings that such distillates could ignite easily and that they should therefore be stored in containers buried in sand.

Al-Kindi was famous for his perfume distillations, which he wrote about in the *Book of the Chemistry of Perfume and Distillations* in the 9th century. In this he described a distillation process, '... and so one can distil wine using a water bath it comes out like rosewater in colour. Also vinegar is distilled and it comes out like rosewater in colour.'

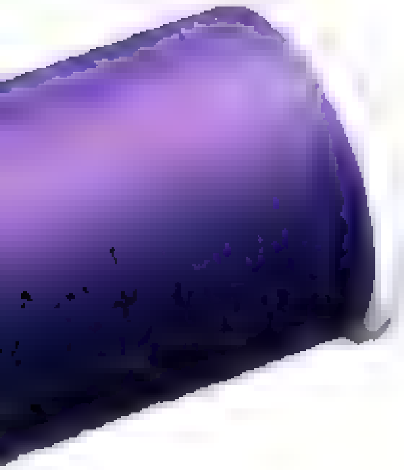
Ibn Badis from Tunisia, nine centuries ago, described how silver filings were pulverized with distilled wine to provide a means of writing with silver. He said, 'take silver filings and grind them with distilled wine for three days, then dry them and grind them again with distilled wine until they become like mud, then rinse them with water ...'

As we have said, for Muslims alcoholic drinks are *haram* or forbidden, but their interest and discovery of it through distillation was intended to use its beneficial and harmless elements. Its discovery has given rise to a huge number of products in industries from pharmaceuticals to cosmetics. Much of their work a thousand years ago had practical application and with their research new items could be manufactured, like ink, lacquers, solders, cements and imitation pearls. As well as individual products, industries began to flourish then as well.

Among the key experiments that marked the beginning of synthetic chemistry were those of al-Razi, when he described how to obtain mercuric chloride as 'corrosive sublimate' in *On Alums and Salts*. This, coupled with the discovery of chloride of mercury, today used in pesticides, inspired the discovery of other synthetic substances. The discovery of corrosive sublimate, and the fact that it was capable of chlorinating other materials, began the unearthing of mineral acids. Corrosive sublimate today has important applications in medicines as an astringent, stimulant, caustic and antiseptic.

In the field of industrial chemistry and heavy chemicals, one of the greatest advances of medieval times was the isolation and manufacture of alum from 'aluminous' rocks, through artificial weathering of alunite. Alum was used in papermaking, paint production and the production of sulphuric acid. It was Jabir who discovered acids like sulphuric and hydrochloric. The Muslims were also crystallizing 'ammonia alum' or ammonium aluminium sulphate.

To read more about these individual chemists mentioned here go to the School chapter and the section on 'Chemistry'.



Textile Industry

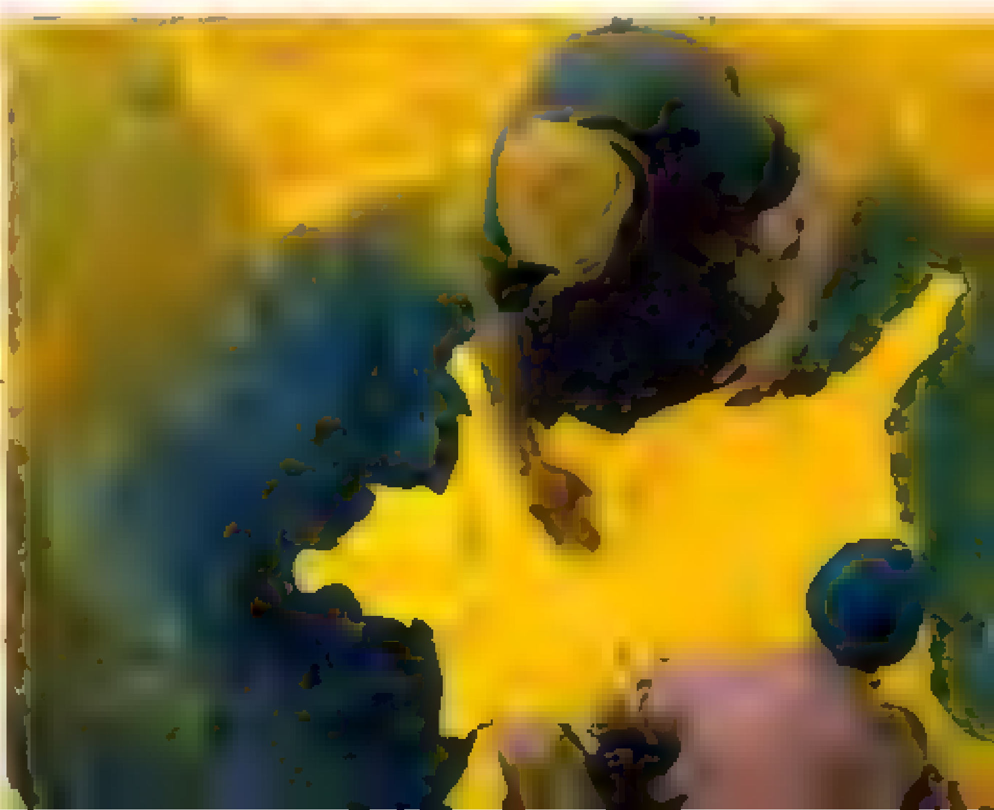
TEXTILES DROVE MUCH OF THE MEDIEVAL TRADE, AND they were an exceptionally important part of the economy. It's estimated that textile manufacture and trade at this time would have kept the majority of the working population busy.

By the mid 9th century the textile fabric of Muslim Spain had earned an international reputation, and even three centuries later Spanish silks with golden borders and ornamentation were used at the marriage of Queen Beatrix of Portugal.

The Spanish Muslims had as much delicacy and craftsmanship in their work as the famous Chinese artisans. In Cordoba alone, there were three thousand weavers making carpets, cushions, silk curtains, shawls, divans and 'Cordovan' leather for the 'cordwainers' (cordobanes) of Europe, all of which found eager buyers everywhere. They were also producing superb woollen stuffs, especially rugs and tapestries, made in Chinchelia and Cuenca. These were used as prayer mats as well as table and floor decorations in their beautiful houses.

In al-Andalus, the production of Eastern-style cloth was concentrated in the towns of Malaga and Almeria, and because they were ports they were also the first to receive the new styles and techniques. From Muslim Spain the textile industry spread widely up into Europe.

Left to right: 19th-century manuscript from the book *Album of Kashmiri Trades* showing a dyer at work dyeing cloth; tanners applying saffron dye to cow hide in Fez, Morocco.



The Ka'bah in Mecca, Saudi Arabia, covered by the [illegible] with golden calligraphy. This is the place towards which Muslims [illegible] the world face [illegible] their five daily prayers. The Ka'bah is a [illegible] walled [illegible] covered by the [illegible]. The [illegible] is shown on the left. The Ka'bah was [illegible] on the location [illegible] the first ever place of worship [illegible] by Adam (pbuh) [illegible] Muhammad (pbuh), Arabs used it to house their statue gods [illegible] were destroyed by the [illegible] nothing inside. It is cleansed every year by the king and his guests and nobody else [illegible] inside. [illegible] on the left houses a footprint believed to be that of Abraham (pbuh). As part of the rituals, Muslims circle the Ka'bah seven times [illegible] God's Oneness.

Further east and along the Mediterranean shores, textiles were made into clothing and the bulk of household furnishings. Nomad women wove tent bands, saddlebags, cradles, and other trappings for their mobile lives. Even in the urban centres and palaces furnishings were mainly of carpets, covers, curtains, and hangings of various kinds. Instead of chairs, people sat on cushions and leaned against bolsters all covered with cloth whose quality and richness reflected their owners' financial status.

Textiles were important political tools as well. They made lavish diplomatic gifts, and it was customary to reward high officials and other favourites, at regular intervals and on special occasions, with robes of honour, turbans, and other garments woven in the rulers' own houses. It was also the caliphs' prerogative, and after 1250 that of the Mamluk sultans, to provide each year the new *kiswa*, the richly ornamented garment that veiled the Ka'bah at Mecca.

The full array of textiles were available to the Islamic world. Wool and linen were produced in quantity from Iran to Spain, and additional supplies of linen were imported, it was so popular. Cotton, native to India, was probably first produced on a large scale in the Mediterranean after the Muslim advance. It grew in Syria and Palestine as well, and from southern Spain it slipped into Europe. Leather was also an important industry and in the reign of al-Mansur in the 12^{th} century Almohad dynasty in Fez, there were 86 tanneries and 116 dye works.

Some towns and cities were internationally recognized for their products. Shiraz was famous for its woollen cloths, Baghdad for its baldachin hangings and tabby silks, Khuzistan for fabrics of camel's or goat's hair, Khurasan for its sofa covers, Tyre for its carpets, Bukhara for its prayer rugs and Herat for its gold brocades. No samples of these products from this period have survived the wear and tear of time though, although textile pieces

Left to right: *Maqamat* or *Assemblies* of al-Hariri, showing a girl working at either a spinning wheel or a spool winding machine in Baghdad, Iraq; a silkworm on a mulberry branch in a Turkish carpet factory today. Back in the 1620s, King James I of England was so fascinated with Persian silk that he tried to establish his own silk industry. He bought silkworms and employed a manager of the royal silk works.

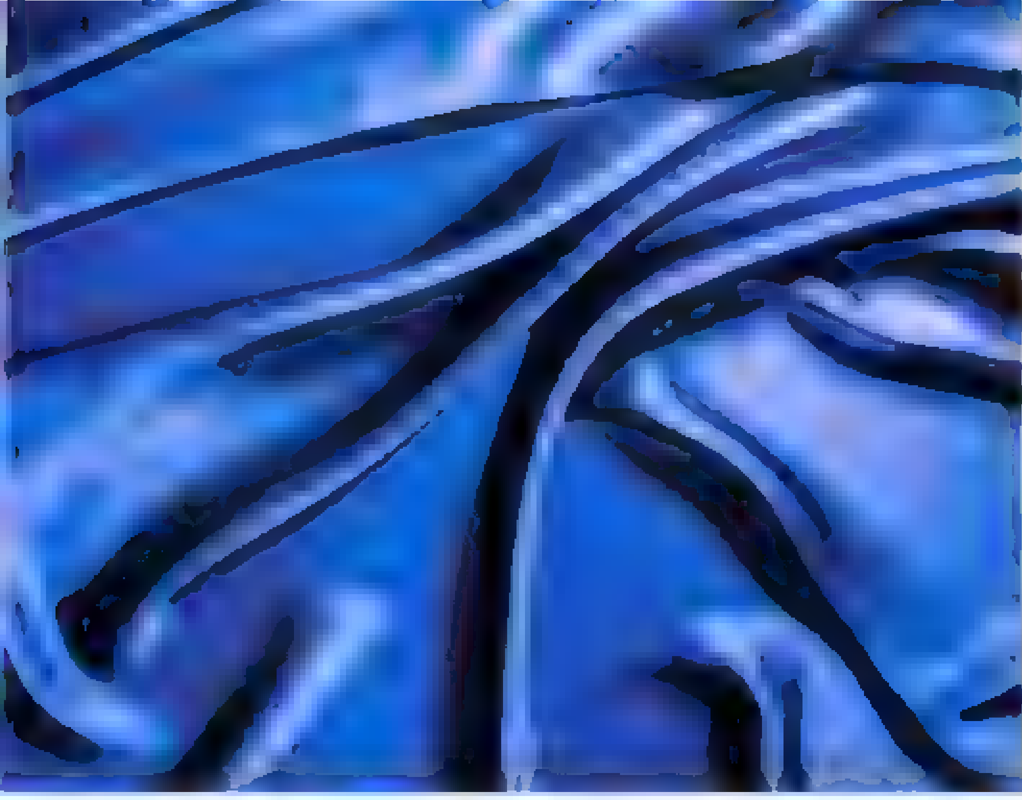
from other periods can be found in Western museums and collections of Eastern art. One of the most precious fragments is the silk cape of an Egyptian Mamluk Sultan, on which was inscribed: 'the learned Sultan' dating from the 14th century. This was found in St Mary's Church, Danzig.

Europe's fascination with Muslim textiles goes back to the Middle Ages, when they were imported by crusaders and traders. They were so valued that Pope Sylvester II was buried in luxurious Persian silk cloth. Queen Eleanor, the Castilian Bride of King Edward I, brought to England Andalusian carpets as precious items of her dowry in 1255.

By the 17th century, trade relations with England were booming, which coincided with the peak of Persian textiles. In 1616, the Persian Shah credited England with three thousand bales to encourage trade, and after this Persian silk was at the top of the list of imports. Three years after this, the ship *Royal Anne* brought in eleven bales of Persian silk, which came via Surat to England. The king at the time, James I, was so fascinated with Persian silk that he considered establishing a silk industry in England. He acquired silkworms and made special arrangements for their nursery at his country estates and Whitehall gardens. He also ordered Frenchman John Bonoeil, the manager of the royal silk works, to compile a treatise dealing with techniques of silk production, which was published in 1622.

Around the same time, trade with India was prolific, thanks to the active role of the East India Company in introducing Indian chintz to England. This fabric was cotton painted with Muslim elements, which provided a model for European cotton as well as wallpaper production.

By the 17th century, imported Muslim textiles were all the rage with the new bourgeois European society, and local industry was threatened. Local silk weavers complained in 1680, while French and British silk and wool merchants sought bans on the East India Company, unwilling to put up with the competition from the foreign textiles.



Left to right: Muslim silk was so popular with the new bourgeois European society that local industry was threatened, so in 1700 the British government introduced a mandatory act restricting its import; a self-portrait done in pastels by Jean Etienne Liotard, an influential Swiss artist who loved Turkish fabric and dress.

The British government reacted in 1700 by introducing a mandatory act restricting the import of Muslim silk, which also prohibited the importation Indian chintz, Persian and Chinese fabrics. The merchants won restrictions on the purchase of these items in their respective nations.

Fine silk didn't only come from Persia, as the Turkish textile industry produced it as well. It was found in outstanding quality in Bursa, where silk weavers produced stunning pieces decorated with Iznik floral motifs, and you can read more about these in the 'Pottery' section. From here silk and velvet reached the sultans' households, and were used in the Ottoman household on sofas, divans and curtains, becoming essential for the interior décor. Lady Montagu, about whom you can read in the 'Vaccination' section of the Hospital chapter, mentions the fame of Turkish textiles and admired Turkish dress sense by wearing it herself.

Another 18th-century fan of Turkish fabric and dress was the influential Swiss artist, Jean Etienne Liotard, who lived in Istanbul for five years and dressed like a native Turk. His female portraits of 'sitters en sultane' greatly helped to spread the fashion of Turkish dress throughout Europe.

We have products today that still bear their Muslim names, like muslin from the city of Mosul, where it was originally made; damask from Damascus; baldachin ('made in Baghdad'); gauze from Gaza, a seaport on the south Palestinian coast; cotton from Arabic *qutn* meaning raw cotton; and satin from Zaytoun, where Muslim traders imported rich fabric from the Chinese port of Tseutung.

To read more about the impact of the textile industry see the section on 'Carpets' in the Home chapter.

Vaccination

VACCINATION TODAY IS A CONTROVERSIAL ISSUE, and it was first rejected when it was first brought to England from the Turks nearly three hundred years ago. The Anatolian Ottoman Turks knew about methods of vaccination. They called vaccination *Ashi*, or engrafting, and they had inherited it from older Turkic tribes.

Vaccination is a process where a person is given a weakened or inactive dose of a disease-causing organism. This stimulates the immune system to produce antibodies to this specific disease. Today, the development of new vaccines takes eight to twelve years, and any new vaccine has to be rigorously tested before it can be accepted as safe.

The Turks had discovered that if they inoculated their children with cowpox taken from the breasts of cattle, they would not develop smallpox. This kind of vaccination and other forms of variolation were introduced into England by Lady Montagu, a famous English letter-writer and wife of the English ambassador at Istanbul between 1716 and 1718. She came across the Turkish methods of vaccination and became greatly interested in smallpox inoculation after consenting to have her son inoculated by the Embassy surgeon, Charles Maitland.

Whilst in Istanbul, Lady Montagu sent a series of letters to England in which she described the process in detail. On her return to England she continued to spread the Turkish tradition of vaccination and had many of her relatives inoculated. She encountered fierce opposition to the introduction of inoculation, not only from the Church authorities who used to oppose any intervention, but also from many physicians. Through her tenacity though, inoculation became increasingly widespread and achieved great success.

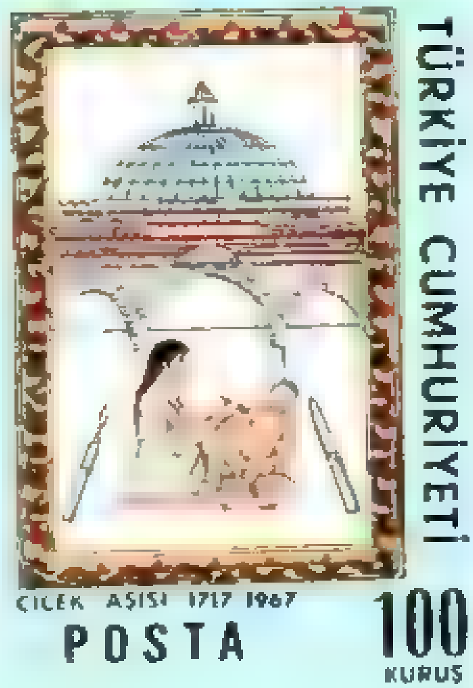
Lady Mary Wortley Montagu (1689–[illegible]) who introduced smallpox vaccination from Turkey into England

The breakthrough came when a scientific description of the vaccination process was submitted to the Royal Society in 1724 by Dr Emmanual Timoni, who had been the Montagu's family physician in Istanbul. Inoculation was then adopted both in England and in France, nearly half a century before Edward Jenner, to whom the discovery is attributed.

It is currently believed that in 1796 Edward Jenner 'heard' that cowpox provided immunity to smallpox when he saw the case of James Phipps, an eight-year-old boy, who was infected with cowpox from a cut on the hand of a milkmaid, Sarah Nelmes.

In 1967 Turkey commemorated the 250th anniversary of the first smallpox vaccination. The stamp shows a child being inoculated. In the background is an Islamic dome and, in the foreground a surgeon's scalpel.

Stamp issued by the Turkish Postal Authority in 1967 depicting the 250th anniversary of the first smallpox vaccination



'For more than two hundred years, vaccines have made an unparalleled contribution to public health.... Considering the list of killer diseases that once held terror and are now under control, including polio, measles, diphtheria, pertussis, rubella, mumps, tetanus, and Haemophilus influenzae type b (Hib), one might expect vaccination to have achieved miracle status....'

Richard Gallagher, editor of the international magazine and website *The Scientist*

The Cow-Pock by James Gillray. An 1802 caricature of vaccination at the St Pancras Smallpox and Inoculation Hospital showing Dr Jenner vaccinating patients

Herbal Medicine

A THOUSAND YEARS AGO GARDENS were also scientific 'field' laboratories, looked after by eminent scientists who wrote manuals on the medical properties of plants. Herbal medicine wasn't seen as an alternative medicine but was very much part of medical practice, with many hospitals keeping gardens full of herbs, for use in medicines, and new drugs were discovered and administered.

This kind of herbal discovery has been made since the dawn of civilization. There are records from Egypt, Mesopotamia, China and India that reflect a tradition that existed before we discovered writing. In the West, the first 'herbal' (a book listing and explaining the properties of herbs) was Greek and written in the 3rd century BCE by Diocles of Carystus, followed by Crateuas in the 1st century CE. The only work that has survived, *De Materia Medica*, was done in 65 CE by Dioscorides. He remains the only known authority amongst the Greek and Roman herbalists.

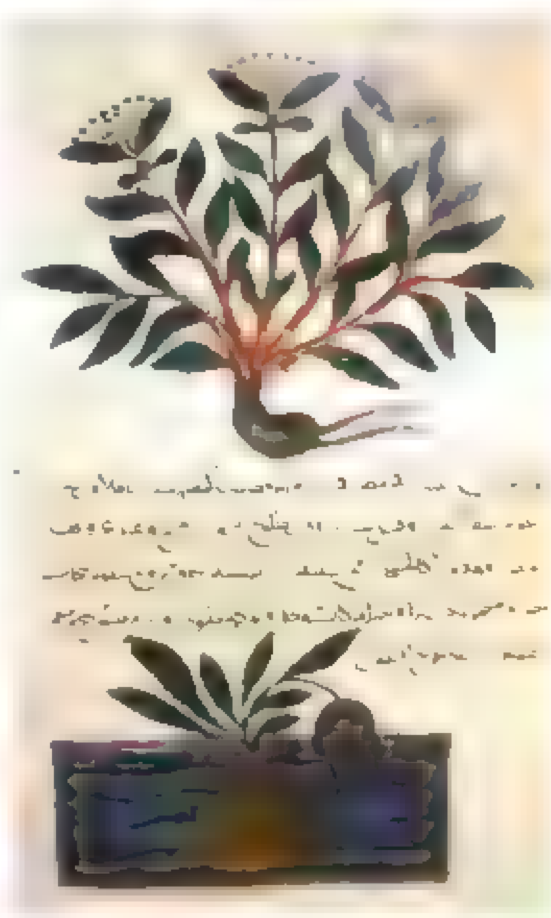
As the Muslim lands grew, merchants and travellers came across exotic plants, trees, seeds and spices previously unknown to them. They collected and brought back a huge number of samples of raw ingredients, along with knowledge, and information about their use, combing the world and its harshest of environments, going as far afield as the Steppes of Asia and the Pyrenees. The discovery and wide use of paper also meant that on-the-spot detailed recording of their journeys and observations could be made.

With this vast amount of data and material, coupled with their scientific medical knowledge, many new traditional and herbal medicines became available. All these discoveries meant that a huge amount of information was built up and spilled out of colossal encyclopaedic works.

'And in it, their drink is mixed with ginger.'

Quran (76:17) mentions ginger as one of the drinks of Paradise. Today ginger is used to relieve nausea and vomiting.

Folio from a 15th century Arabic botanical treatise



Paper

PAPER SEEMS SUCH AN ORDINARY PRODUCT TODAY, but it's fundamental to modern civilization. Think of all the pieces of paper you use every day, from magazines, TV guides and newspapers to kitchen roll and greetings cards.

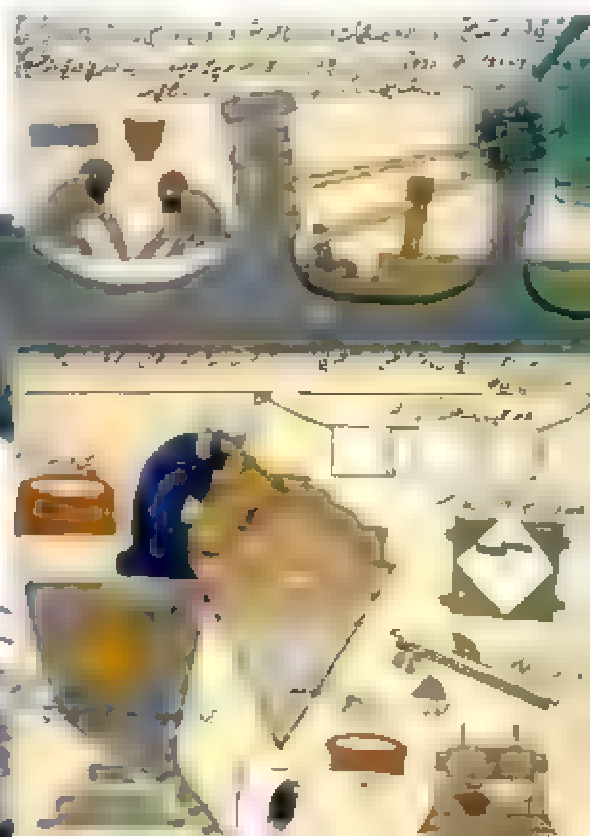
Eleven hundred years ago Muslims were manufacturing paper in Baghdad after the capture of Chinese prisoners in the battle of Talias in 751 CE. The secrets of the trade were passed to their captors and the Baghdad paper mills quickly caught on, with manufacturing spreading west to Damascus, Tiberias, and Syrian Tripoli. As production increased, paper became cheaper and of better quality, and it was these mills in Damascus that were the major sources supplying Europe.

The Syrian factories benefited greatly from being able to grow hemp, a raw material whose fibre length and strength meant it produced high quality paper. Today, hemp paper is considered renewable and environmentally friendly; it also costs less than half as much to process as wood-based paper.

As well as using hemp, the Muslims also introduced linen as a substitute to the bark of the mulberry, a raw material used by the Chinese. The linen rags were broken up, soaked with water and fermented. They were then boiled and cleared of alkaline residue and dirt. These cleaner rags were then beaten to a pulp by a trip hammer, a method pioneered by the Muslims.

They also experimented with raw materials, making cotton paper. A Muslim manuscript on this dating from the 11th century was discovered in the library of the Escorial in Madrid.

Left to right: Ancient methods of forming sheet paper can be seen here, as a craftsman forms a sheet of paper in Kashmir, India, 1917; 17th century manuscript showing the papermaking process.



By 800, paper production had reached Egypt, and possibly the earliest copy of the Quran on paper was recorded here in the 10th century. From Egypt, it travelled further west, into North Africa and Morocco. Like much else, from there it crossed the straits into Muslim Spain around 950, where the Andalusians soon took it up, and the town of Jativa, near Valencia, became famed for its manufacture of thick, glossy paper, called *Shatibi*. Within two hundred years of it being produced in Baghdad's mills, paper was in general use throughout the Islamic world.

This meant that producing books became easier and more cost effective because paper replaced the expensive and rare materials of papyrus and parchment, so mass book production was triggered. Before this, production had been complex and highly sophisticated: complex in that it was done through the labour of copyists, and sophisticated because of the skilled hands involved. The amount of labour in production decreased but the sophistication of the craftsmanship remained, so in the Muslim world hundreds, even thousands of copies of reference materials were made available, stimulating a flourishing book trade and learning.

The expansion of paper manufacturing kick-started other professions, like those of dyers, ink makers, manuscript craftsmen and calligraphists; the sciences also benefited. The pioneering Tunisian, Ibn Badis from the 11th century, described this in his *Staff of the Scribes*, writing about the excellence of the pen, the preparation of types of coloured inks, colouring of dyes and mixtures, secret writing and the making of paper.

The first paper mill in Christian Europe was established in Bologna in 1293 CE, and by 1309 the first use of paper in England was recorded. With all this paper and more cheaply produced books, the diffusion of knowledge into Europe speeded up.

Danish historian Johannes Pedersen said that by manufacturing paper on a large scale, the Muslims 'accomplished a feat of crucial significance not only to the history of the Islamic books but also to the whole world of books.'

Muslims developed techniques for decorating paper that are still used for good writing paper and in books today. One was marbling, which gave the paper a veined life-like look, and was used back then to cover important manuscripts.

The word for marbling in Turkish is ebru, which means cloud or clouds, or abru, which means water face. Ebru comes from one of the older Central Asia languages which means 'veined paper' or paper. Its origin might ultimately go back to China and it was through the Silk Route that marbling came first to Iran and then moved towards Anatolia, picking up the ebru name.

At the end of 16th century, tradesmen, diplomats and travellers coming from Anatolia brought the marbling art to Europe and after the 1550s it was prized by European bookbinders, becoming known as 'Turkish Paper' or 'Turkish marbled papermaking'. After, it was widely used in Italy, Germany, France and England.

Texts about ebru, like Discourse on decorating paper in the Turkish manner, *published in 1664 by Athanasius Kircher, a 17th century German scholar in Rome, also spread the knowledge of marbling art.*

Pottery

FOR OVER A THOUSAND YEARS, Muslim lands produced some of the world's finest ceramics and pottery. They were traded, bought as ornaments and used domestically in cooking, lighting and washing. A millennium later, these pots have been turning up in European archaeological digs.

Pot-making was a serious business and trade. The late 14th-century historian al-Maqrizi said in Cairo: 'Daily there is thrown on to the refuse heaps ... to a value of some thousand *dinars* ... the discarded remains of the red baked clay in which milk-sellers put their milk, cheese-sellers their cheese, and the poor the rations they eat on the spot in the cook shops.'

In the East, pottery centres developed at Baghdad and Samarra, Iraq. Excavations at Samarra, the residence of the caliphs from 838–883 CE, show us they had glazed and unglazed pots, incised and stamped, and that there were three main types. One was white, decorated with spots or pseudo-calligraphic motifs in cobalt blue. The second was decorated in polychrome, two-tone stripes, inspired by Chinese stonewares of the T'ang period in the 7th and 8th centuries. The third pot type had a special lustre, a decoration that looked metallic.

These pots were skilfully made, in a similar way to the modern potter's wheel today, then dried and fired in kilns. They became collectors' items and icons of beauty and art, because what the Muslims did better than the Romans before them was to improve and introduce new ways of glazing, colouring and decorating their pottery.

Pottery has continued to be an art

14th century earthenware jar this Mamluk lustre from [illegible] was found at Trapani in Sicily

They first improved lead glazes with relief designs. The Romans had spread mostly red earthenware with shiny green or yellowish brown glazes to Mediterranean countries including Egypt. By adding more lead, the early Muslims produced a smoother, more brilliant finish to the pot and made it impermeable so it could hold liquids.

The Abbasid potters then took the lead glaze and added tin oxide to it, because they were trying to find a way of making pure white porcelain, like the expensive Chinese variety. The raw materials of Iraq and China were totally different, so the resourceful Muslim potters introduced a dash of tin oxide instead. This caused greater opacity and the exact white finish they were looking for.

Not satisfied, the potters then made innovations in the design, producing the 'blue-on-white' decoration, which was later re-exported to China, where it became hugely popular and spread onto their porcelain too. The 'blue-on-white' ceramics were a source of pride for the Abbasid potters, who added their signature to much of their work. In one of these signatures a potter, named Abawayh, referred to himself as "*sani' amir al-mu'minin*", telling us that he was the craftsman of the caliph, a reference to the caliphal promotion and patronage of crafts and pottery in particular.

One of the most impressive decorations that appeared later was the lustre glaze. Muslims were eager to develop this in an attempt to produce a close version of the golden and silver vessels of Paradise described in the Quran.

In the 8th century, potters working in Iraq developed a mysterious process called lustre. This was described as an "extraordinary metallic sheen, which rivals even precious metals in its effects, all but turning objects of clay to gold" explains TV Presenter Amani Zain in the BBC's *What the Islamic World Did for Us*.

Lustre provided the right ingredients for producing these in a cheap and acceptable way, as Islam prohibits the use of gold and silver vessels.

The technique involved mixing silver or copper oxides with an earthy vehicle, such as ochre, and then vinegar or grape juice were added as a medium. The 8th century Iraqi potters discovered that if they painted patterns with this mixture on the glazed coating of the clay, then put the wet pot into a kiln for a smoky and subdued second firing, a thin layer of metal was left. After wiping off the ash and dust, an amazing iridescent glow came through.

What was happening was that the copper and silver oxides separated out in the firing, leaving metal as a thin film on the surface of the tin glaze. Silver left a paler yellow or golden and silvery effect, and copper produced a darker, redder, ruby colour. The iridescence of these tones varied according to the fall of light. Exquisite monochromes and polychromes, in gold, green, brown, yellow, and red, in a hundred almost fluid tints, were possible.

Decorated tiles were also made in this way. The rich colours of these squares, and their harmonious combinations, gave the mosques and palaces a regal splendour.

'We are all drawn to beauty and the Islamic empire was no exception. That's why the Arabs invented the technique that makes these clay pots into art.'

BBC presenter Amani Zain talking about lustre glaze on *What the Islamic World Did for Us*

This lustre technique from Baghdad passed through the Muslim world, and 9th-century Qayrawan in Tunisia starting producing lustre tiles as well. Another century later it reached Spain. Archaeological finds at Madinat al-Zahra', the caliphate's city near Cordoba, uncovered a huge amount of pottery with patterns that have been made with manganese brown for the painted lines and copper green for the coloured surfaces. A few centuries later, al-Andalus had its own centres of production like Malaga, producing gold-lustred dishes and large jars like the 'Alhambra Jar'.

BBC presenter Amani Zain, on *What the Islamic World Did for Us*, said that "These amazing vases [the Alhambra Jar] were originally used for storing oil and grains. But in the palaces of the Caliphs their designs took on an extraordinary beauty. And for those who saw them, they must have thought they'd been made from precious metals."

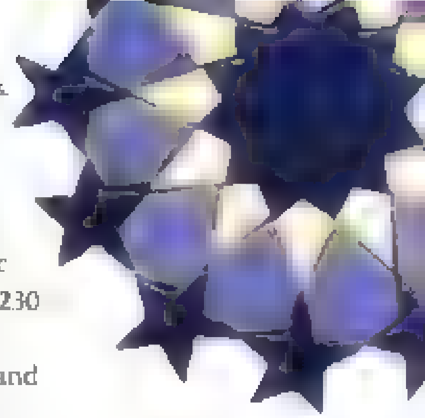
Ordinary people needed practical pots, and in Spain the most popular pot was a *qâdûs*, which carried water on the *noria*, a waterwheel, which you can read about in the 'Raising Water' section of this chapter. It became the universal unglazed pot, and must have been the mainstay of the rural pottery industry until it was replaced by tin fairly recently.

As well as producing the necessary water-carrying pots, Spanish Muslims at the beginning of the 12th century were replacing Byzantine mosaics with tiles and *azulejos*. These were beautiful tiles in blue and white, covered with geometric, floral and calligraphic patterns. These glazed faience tiles of Malaga are still famous. We know that the blue glaze of cobalt oxide, which the *azulejos* are decorated with, came from the East to Malaga, from where it spread to Murcia, then to Christian Spain, and Valencia at beginning of the 14th century, and thence to Barcelona by its end.

Present-day Turkey was also a thriving pottery centre because craftsmen crowded here, to the city of Konya, as they fled from the invading Mongols. The collapse of the sultanate of Konya at the beginning of the 14th century brought the ceramic production of Anatolia to a standstill, but it was to have a brilliant revival when the Ottoman Turks made Bursa their capital in 1326. The city rose again with fine buildings covered in ceramic tiles.

Even busier in production than Bursa was Iznik, which was the real centre of the industry, and it flourished for two centuries from the end of the 14th century. A typical Iznik decoration was painted on slip, in cobalt blue, turquoise and green from copper, which were outlined in black with an amazing tomato red in low relief. The patterns, made up from rectangular tiles, were all floral motives, with four flowers traditionally being used. These were the rose, jasmine, carnation and tulip.

Andalusian geometric tile segments.



Muslim potters monopolized the skills of glaze and lustre decoration for over ten centuries, and pottery of today is indebted to them. From the potters of Spain and Sicily, new modes and methods of pottery production, materials and colours entered Europe. Europe didn't know about tin glaze until the Muslims introduced it to Spain in the 9th century.

There is plenty of evidence today that Muslim pots did travel outside Spain, as Malagan pottery has been found in England; forty-four pieces of Moorish lustre were discovered in Britain dating back to late 13th and 14th centuries, and another twenty-two pieces were from the 15th century. More recently, in 1990, excavations in Longmarket in the centre of Canterbury uncovered a large amount of Islamic lustre and turquoise blue pottery.

Nigel Macpherson-Grant, who worked on the Canterbury find, tells us how Muslim pots came to be in England: 'Some pots may have made their way back to England in the baggage of Crusaders returning from the Holy Land…. Another possibility is that medieval pilgrims either to the Holy Land or to the famous shrine of St James at Compostella in Spain might have brought back the occasional Islamic pot as a souvenir.' On rare occasions the route was more direct. We know, for instance, that in 1289 Eleanor of Castile, the Spanish wife of Edward I, ordered four thousand pots of '*Malik*' for the royal household. In this case '*Malik*' almost certainly refers to Malaga – the main centre for Andalusian lustrewares.' (Malik refers to Malika which is the Arabic name of Malaga.)

A 15th-century lustre dish was found at a site called Blossom's Inn in London, and was decorated with the tree of life and *Kufic* inscriptions. These were popular in Andalusia and North Africa at that time, and were copied everywhere in Europe. Amazingly the dish's entry into England was recorded in 1303 in the accounts of the New Custom on goods imported and exported by aliens at the port of Sandwich, Kent. The dish is now at the Guildhall Museum of London.

Another famous ceramic brand left to us by Muslim potters is the so-called Maiolica ware. The story started at Majorca and other Balearic islands, which were under Muslim rule until 1230. Italian ships, mainly Genoese and Venetians, often called there to collect tin glazed pottery and recruit Moorish potters, who brought to Sicily the Majorcan pottery style. This was gradually established as a leading style, becoming renowned as 'Majolica' or 'Maiolica'.

Since the 15th century, Majolica has reached an astonishing degree of perfection, using the same production and decorative techniques as the Andalusians and Egyptians. Later, Italian artists developed it into new varieties, like Gubbio lustre, which came in greenish yellow, strawberry pink and a ruby red. This Maiolica pattern has dominated the ceramic industry in Italy till the present time.

Muslim pots were seen as status symbol in Europe because of their exquisite quality and decoration, so finding these pots tells us today what kind of people lived in places like Blossom Hill and Longmarket nearly five hundred years ago. Today the art of Muslim potters lives on in the Andalusian tiles and mosaics that still adorn modern cafes, as the designs have become a part of the South's identity.

arly 16th-century Serpent Dish, made by Iznik potters in Turkey

Glass Industry

What we know today about glass in the past has come from archaeological digs and writings of travellers from the time. So we know that 13th and 14th century Syria was a great centre of this fine material, in the cities of Aleppo and Damascus. Ibn Battuta described Damascus as a glassmaking centre when he travelled through there in the 1300s. Not only Syria, but Egypt, Iraq and Andalusia were all producing it in vast quantities from the 8th century onwards, and it was either cut from crystal or blown in moulds.

Muslims had inherited the famous Roman glass industry based in Syria and Egypt, developing it with double stamping (in which a stamp with decorative designs was pressed onto hot glass); freeform glassblowing with thread decoration (continuing from Roman and Byzantine traditions); mould blowing (where the glassmaker blows the liquid glass into a prepared mould); and engraving and cutting glass either by hand or with a wheel. They also perfected glass decoration and expanded the variety of products to include bottles, flasks, vases and cups.

By the 13th century, Syrian glass was so fine that merchants and buyers all over the world were after samples, and digging this century has uncovered seven hundred year old Syrian enamelled glass in Sweden and southern Russia, and it even travelled as far as China.

It was Samarra, Iraq, that was really famed for its glass. Amongst the most stunning finds was *millefiori*, or mosaic glass, which was different from earlier types in its peculiar colouring and design. Alongside this, another of the most beautiful finds at Samarra was a 9th century straight-sided bowl in whitish glass.

Right: A glass blower in Venice, Italy

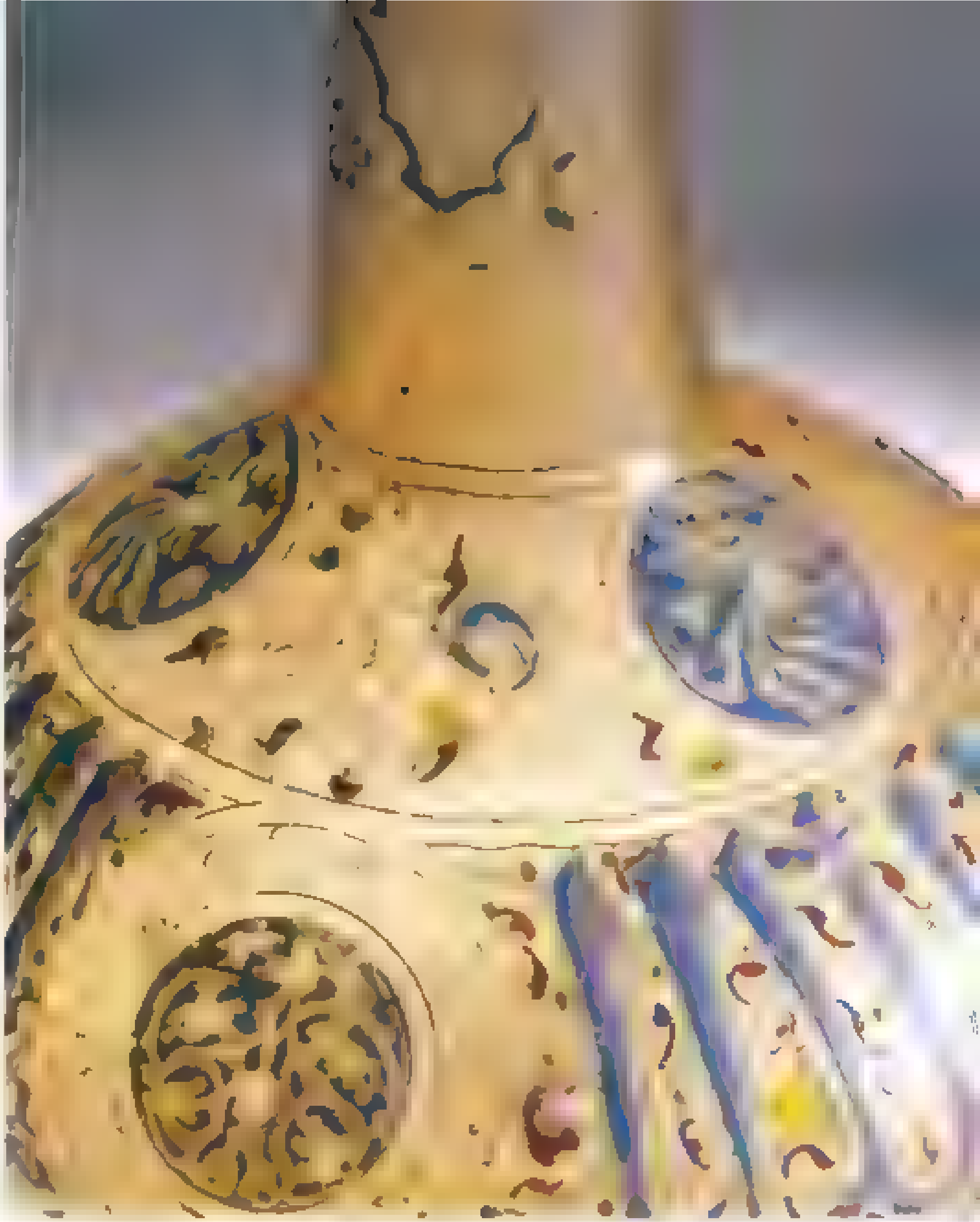
Samarra's glassmakers were also renowned for making small bottles for things like perfumes. Some were pear-shaped, in blue and green glass, with four sides and a nearly cylindrical neck. These were heavier and frequently decorated with cutting. At Samarra, fragments of 9th-century cut glass bowls have also been found with strongly stylized decoration, and these are of outstanding beauty.

So much glass has been uncovered in excavations at al-Fustat, 'Old Cairo,' which was founded in the 640s CE, that from the 8th century to the later Middle Ages this town must have been a centre of production. The earliest dated items, from 708, are coin-like weights, stamped with the names of rulers or government officials. They came in a variety of colours, from dark green, light green and turquoise, to white and purple. Some of the most sophisticated Egyptian glass vessels were decorated with lustre, a shiny, sometimes metallic effect, made by painting copper or silver oxide on the surface of the object, which then was fired at a temperature of about 600°C (1112°F).

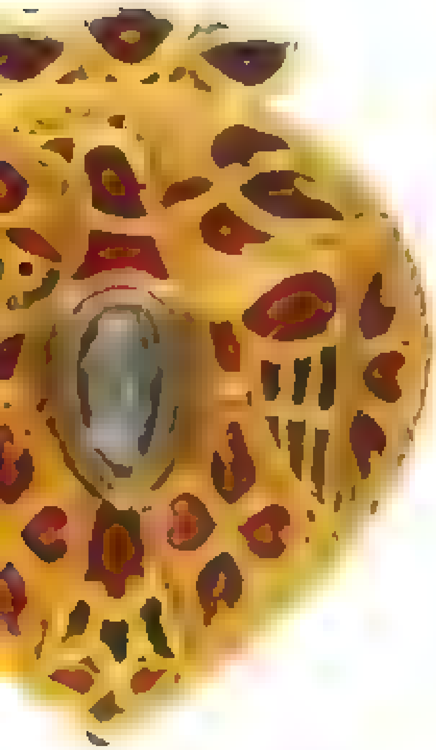
The glass industry wasn't restricted to the East, because in al-Andalus the industry was in the same great demand as the pottery. Jars with two, four or eight handles, and bowls with handles and ribs have all been found. The chief centres for glass works were in Almeria, Murcia and Malaga, and it was Almeria that had a worldwide reputation. Glass goblets blown in Almeria, Malaga and Murcia imitating eastern wares were found on the tables of nobles in 10th-century Leon.

The technique of cutting crystal was said to have been introduced by 'Abbas ibn Firnas in 9th-century Cordoba, al-Andalus. He was a scholar and inventor in the courts of Abd al-Rahman II and Muhammad I, who could also decipher the most complex writing and attempted to fly by building artificial wings. With glass, he understood its scientific properties and contributed to the early experimentation with lenses and the idea of magnifying scripts, after establishing Andalusia's crystal industry based on mined rocks.

So, glass had a colourful history as it travelled from the furnaces of Syria, Egypt, Iraq and Andalusia all round the world, adorning people's tables and houses as a status symbol and practical necessity. From windows to watch fronts, TVs to thermochromic glasses, aquariums to incubators, glass continues to make our lives easier.



14th-century gilded and enamelled glass bottle from Egypt. The inscription reads 'Glory to our Master the Wise, the Just King'.



17th century gold pendant from India. This gold pendant is inlaid with flat-cut rubies and emeralds and a large tabled diamond in the pattern of a flying bird, against a leafy background of rubies.

'The earth is like a beautiful bride who needs no manmade jewels to heighten her loveliness.'

Raw Jewels

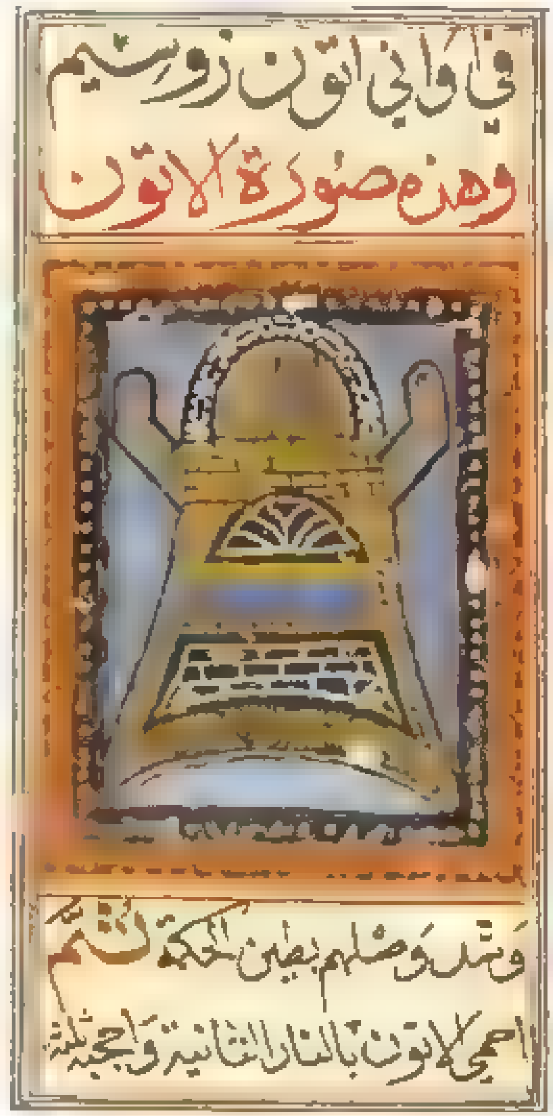
As you'll have read, the glass, textile, pottery and paper industries formed the backbone to a successful empire whose goods were traded as far as China. Other vital industries included goods from mines and the sea, like jewels and pearls. Emeralds were extracted in upper Egypt, turquoises taken in Farghana, rubies reaped in Badakhshan, and cornelian and onyx obtained in Yemen and Spain.

The cinnabar mines of Almaden in Spain had a workforce of somewhere near a thousand, some cutting the stone down in the pit, others transporting the wood for smelting, making the vessels for melting and refining the mercury, and manning the furnaces.

A surprisingly precious mined item was salt, or white gold, at Hadramawt (in Yemen), Isfahan, Armenia and North Africa, which was carried in great camel caravans. 'Throughout the greater part of Africa,' writes Leo the African, a medieval historian and geographer who roamed Africa and the Mediterranean lands in the 16th century, 'salt is entirely of the mined variety, taken from underground workings like those for marble or gypsum.'

Precious stones were dressed and polished with emery, found in Nubia and Ceylon. Egypt and the Sudan both had alum, and parts of western Egypt, notably the famous desert of Nitro, had natron, which was used for whitening copper, thread and linen, and also for curing leather. It was in demand with dyers, glassmakers and goldsmiths; bakers even mixed it in with their dough and meat cooks used it as a tenderizer.

From the sea came the beautifully smooth pearls that decorated many necks across the world. Pearl diving was carried out on both sides of the Persian Gulf, in the Arabian Sea, in Ceylon, near Shiraf and the island of Kish, along the Bahrain coast towards the island



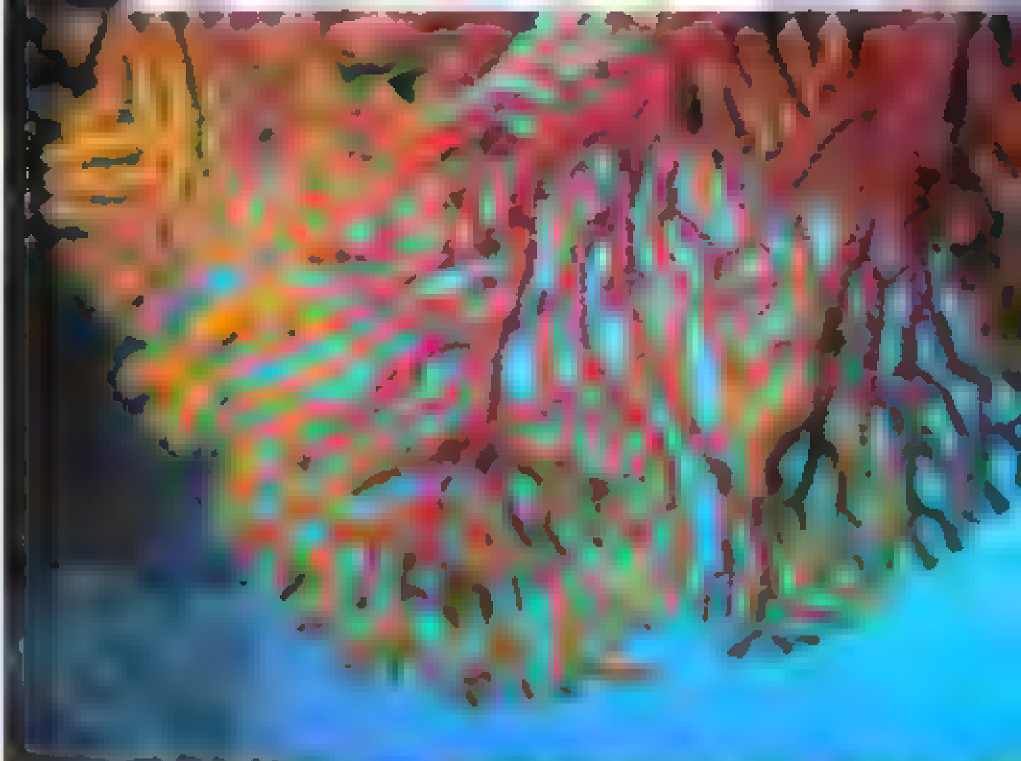
[illegible] century Arabic manuscript showing a furnace for making artificial rubies and sapphires. The Arabic text on the manuscript describes how it works.

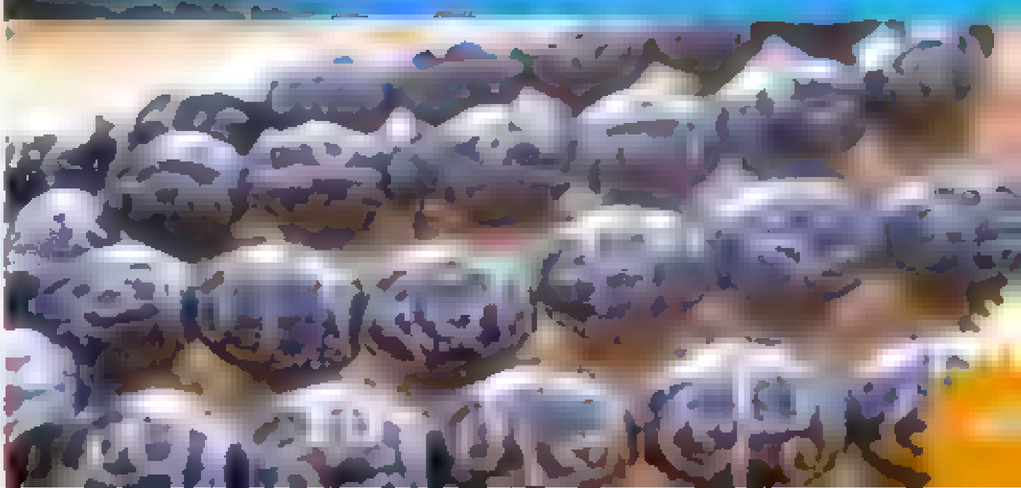
Right top to bottom: Treasures from the sea, such as pearls and coral, were used in jewellery and they continue to fascinate us today. The beads have inscriptions of the name of God on each. In the Quran there are ninety-nine names (attributes) of Allah.

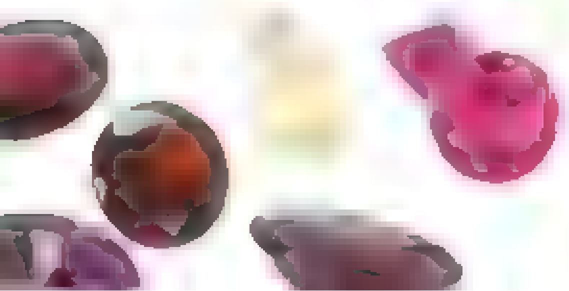
of Dahlak. From the 14^{th} century, Ibn Battuta refers to pearl diving methods. 'The diver attaches a cord to his waist and dives,' he says. 'On the bottom, he finds shells embedded in the sand among small stones. He dislodges them with his hand or a knife brought down with him for the purpose, and collects them in a leather bag slung round his neck. When breath fails, he tugs at the cord, the sign for the man holding it in the boat to pull him up again. Taking off the leather bag, they open up the shells and cut out with a knife pieces of flesh from inside.'

There were coral reefs lying off the coasts of North Africa, near Sicily and Sardinia. Al-Idrisi, the 12^{th} century geographer gives an account of coral gathering: "Coral is a plant which has grown like trees and subsequently petrified deep in the sea between two very high mountains. It is fished with a many-looped hemp tackle; this is moved from high up on the ship; the threads catch the coral branches as they meet them, and the fishermen then draw up the tackle and pick out from it the very considerable quantity of coral."

Coral was then used to decorate weapons, along with pearl, make prayer beads and jewellery. Today, like all jewellery, coral is worn in many styles, from long strands of beads to carved cameos and pins, but prices for this marine beauty can be as much as $50,000 for a fifty millimetre diameter bead as the coral reefs are destroyed and coral as a jewel becomes more scarce.







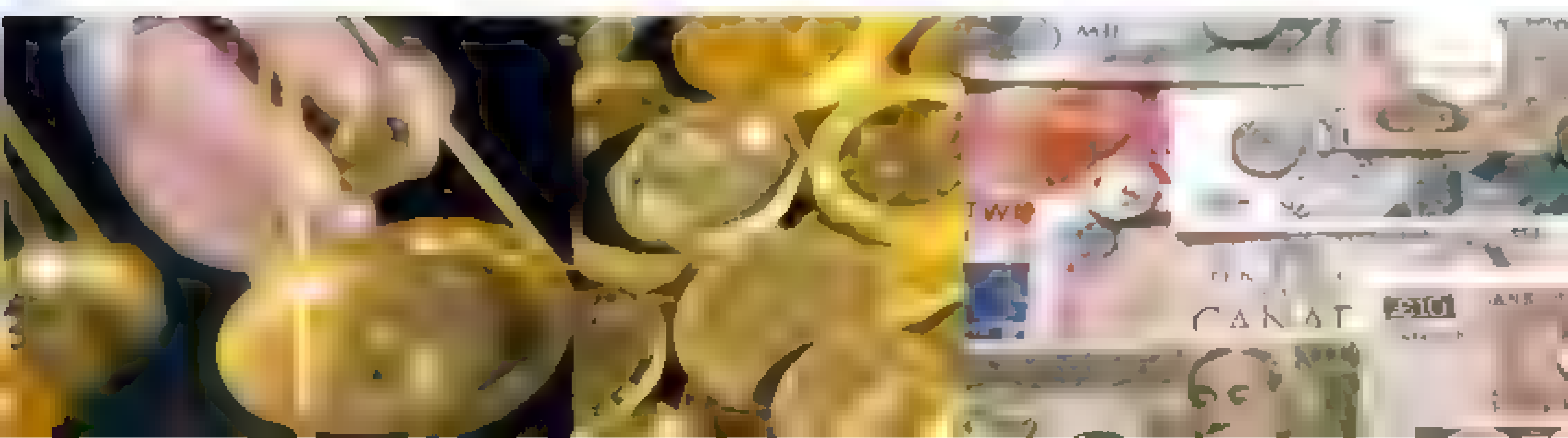
Checkout

IN THE PAST MONEY WAS ALIVE, because camels, cattle or sheep were used to 'pay' for goods. In the time of Ibn Battuta, the 14th century Muslim traveller, the Maldives used cowrie shells as currency as they were highly treasured and prized, and these reached distant regions like Mali in West Africa. Today we use plastic money, notes and coins but this is a small quantity compared to the amount of 'invisible', intangible money shooting around the world as the financial markets make their electronic transfers. One day our coins and notes may be as useful as Ibn Battuta's cowrie shells would be today.

Dar al Islam or the Muslim world spread its wings, even under separate rulers or sultans, using gold and silver coins as its international currency. If we are globetrotting today, we either take travellers cheques or risk having our purses full of different currencies. But in the 14th century, travellers in the Muslim world could scour every market nook and cranny and use *dinars* or *dirhams*, from capital cities to the smallest village.

Step outside the Muslim world and transactions were a different story. Again Ibn Battuta can tell us a lot about the world nearly seven hundred years ago as he had a surprising financial experience in China. He said: "... The people of China ... buy and sell with pieces of paper the size of the palm of the hand, which are stamped with the sultan's stamp. If anyone goes to the bazaar with a silver *dirham* or a *dinar* ... it is not accepted and he is disregarded."

In the 7th and 8th centuries money was mostly made of gold and silver, and Muslims made their coins according to the Quran, which said: 'When you measure, give an exact measure and weigh with an accurate scale' (Sura 17:35). So, it was the caliph's responsibility to ensure the purity and weigh of the coins, and the standard was established by the *Sharia* law as seven *mithqals* of gold to ten *dirhams* of silver. Any coins that didn't measure up, foreign currency and old coins were brought to the mint along with gold and silver bullion to be refined, and struck into new currency. At the mint the bullion was first examined to determine its purity before being heated and made according to the established alloy standards.

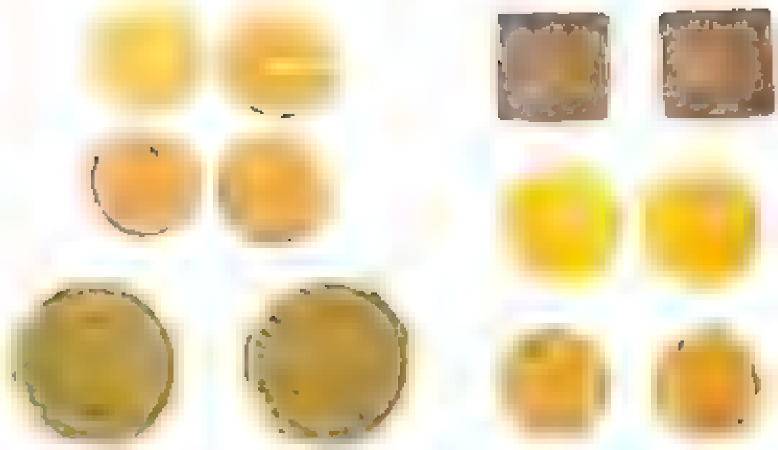


Both *dinars* and *dirhams* were used by different Muslim rulers. The first caliph to make his own coins was Umayyad Caliph Abd al-Malik ibn Marwan, who ruled from 685 to 705 CE. These *dinars* were the first gold coins with an Arabic inscription, as previously money had been silver Sassanian coins, and gold and copper Byzantine coins. By making his own coins in 691 or 692, Caliph Abd al-Malik could now keep his rule independent from Byzantium and unify all Muslims with one currency.

This new coin was copied from the Byzantine currency, the *solidus*. It was similar in both size and weight, and on the face were three standing figures, like the Byzantine coin, which had the figures of Heracles, Heraclius Constantine, and Heraclonas. A big difference was the Arabic testimony of Islam surrounding the design on the reverse: 'In the name of God, there is no deity but God, He is One, Mohammad is the messenger of God.'

The Byzantine emperor was furious with this development, as new money meant competition and he refused to accept it, responding with a new coin. This angered Caliph Abd al-Malik, who made another coin with an upright figure of the caliph, wearing an Arab headdress and holding a sword, again with the testimony of Islam on the reverse, where the coin was also dated. Only eight of these early Arab-Byzantine *dinars*, dated according to the new Islamic calendar, have survived.

The coin throwing continued, and true to form the Byzantine emperor replied with yet another, and at this point in 697 the Caliph had had enough, and introduced the first Islamic coin without any figures. On both sides of this new *dinar* were verses from the Quran, which made each piece an individual message of the faith. He then issued a decree making it the only currency to be used throughout Umayyad lands. All remaining Byzantine and Arab-Byzantine pieces had to be handed to the treasury, to be melted down and re-struck. Those who did not comply faced the death penalty.



Clockwise from top left: Early Umayyad coins, 691–693. The coin on the bottom left shows the column placed on three steps topped with a sphere, replacing the Byzantine cross; Andalusian coin, Silver Nasrid *dirham* of Muhammed I, Granada; early Fatimid coins, Al-Mahdiya, 549; Andalusian coin, Gold Nasrid *dirham* of Muhammed XI, Granada; gold *dinar* of Caliph Abd al-Malik from the Umayyad dynasty, 696–697.

There are two fabled Islamic coins: the One Thousand Mohurs and the One Hundred Mohurs. The first weighed in at twelve kilos of pure gold and the second was a baby in comparison being a mere 1,094 grams of pure gold. Their estimated value today is about ten million and one million U.S. dollars respectively.

The coins were originally minted for the Mogul Emperors Jahangir (son of Akbar the Great) in 1613 and his son Shah Jahan (best known for building the Taj Mahal) in 1639, and were presented to the highest dignitaries.

The One Thousand Mohurs was huge at eight inches in diameter, and over the centuries four or five were mentioned as being reserved for the ambassadors of the powerful rulers of Persia. Only one comparable coin is recorded from a plaster cast in the British Museum, a Two Hundred Mohurs, last reported in India in 1820 and since lost. None of the legendary giant gold Mohurs are known to have survived to this day and it's suspected they were melted down for their bullion value. But we know they did exist because travelers mentioned seeing enormous coins in the Treasury of Shah Jahan.

The new gold *dinars* weighed a bit less than the *solidus*, and the state controlled the accuracy of their weight along with the purity of the gold used. Umayyad gold coins were generally struck in Damascus, while silver and copper coins were minted elsewhere.

After this first coin, more of different values were struck, and after conquering North Africa and Spain, the Umayyads established new mints, each producing coins with the name of their city and date of minting.

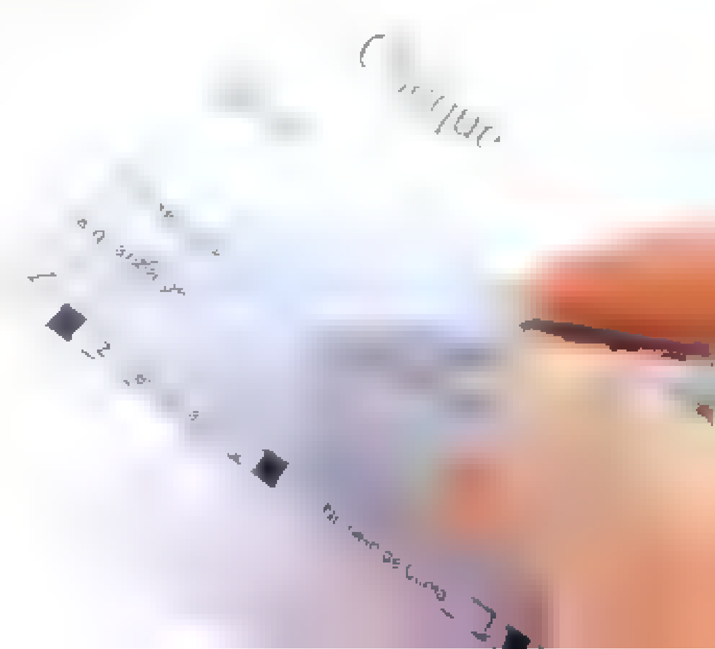
The *dinar* continued to be the main currency used until 762, when Caliph al-Mansur built Baghdad and the gold mint moved to the new capital. The names of persons responsible for the coins began to appear on silver coins called *dirhams*. But these had a short life because the next caliph, Harun al-Rashid, abandoned them when he came to power in 786. He minted *dinars* with the names of governors of Egypt instead, using the two active mints we know about, one in Baghdad and the other in Fustat, the seat of the governor of Egypt.

The Fatimids, who ruled between 909 and 1171, used *dinars* with *Kufic* scripts, and these became the most widespread trade coins of the Mediterranean world because of their high quality and because there were so many of them. When the crusaders captured Palestine, they copied these coins instead of striking their own, and these ranged from excellent copies of the original to bad imitations.

It was from Andalusia that gold *dinars* travelled into Europe from around 711. Then, under the Nasrid rule in Granada from 1238 to 1492, the *dinar* became the *dirham*. These coins were heavy, carefully struck and bore long legends with passages from the Quran and the rulers' family trees. None of the Nasrid coins showed a date, but they are identifiable by their motto 'None victorious save God.' At the same time, in the Christian kingdoms of the north, Arab and French currencies were the only ones used for nearly four hundred years.

After the 13th century, the Muslim Caliphate went from being ruled by one caliph to many small dynasties, each producing their own coins. Like currencies today, they carried the names of various governors from the semi-independent states. These were all minted independently but still acknowledged the nominal leadership of the caliph.

Like today, coins weren't the only ways of paying. Cheques were around centuries ago as well. Cheque comes from the Arabic *saqq*, a written vow to honour payment for merchandise when its destination is reached. In the time of Harun al-Rashid in the 9th century, under a highly developed 'banking system', a Muslim businessman could cash a cheque in Canton, China drawn on his bank account in Baghdad. The use of *saqq* was born out of the need to avoid having to transport coin as legal tender due to the dangers and difficulties this represented. Bankers took to the use of bills of exchange, letters of credit and promissory notes, often drawn up to be, in effect, cheques. In promoting the concept of the bill of exchange, *saqq* or cheque, Muslims made the financing of commerce and intercontinental trade possible.



An artist's impression of [illegible] century merchants

King Offa and the Golden Coin

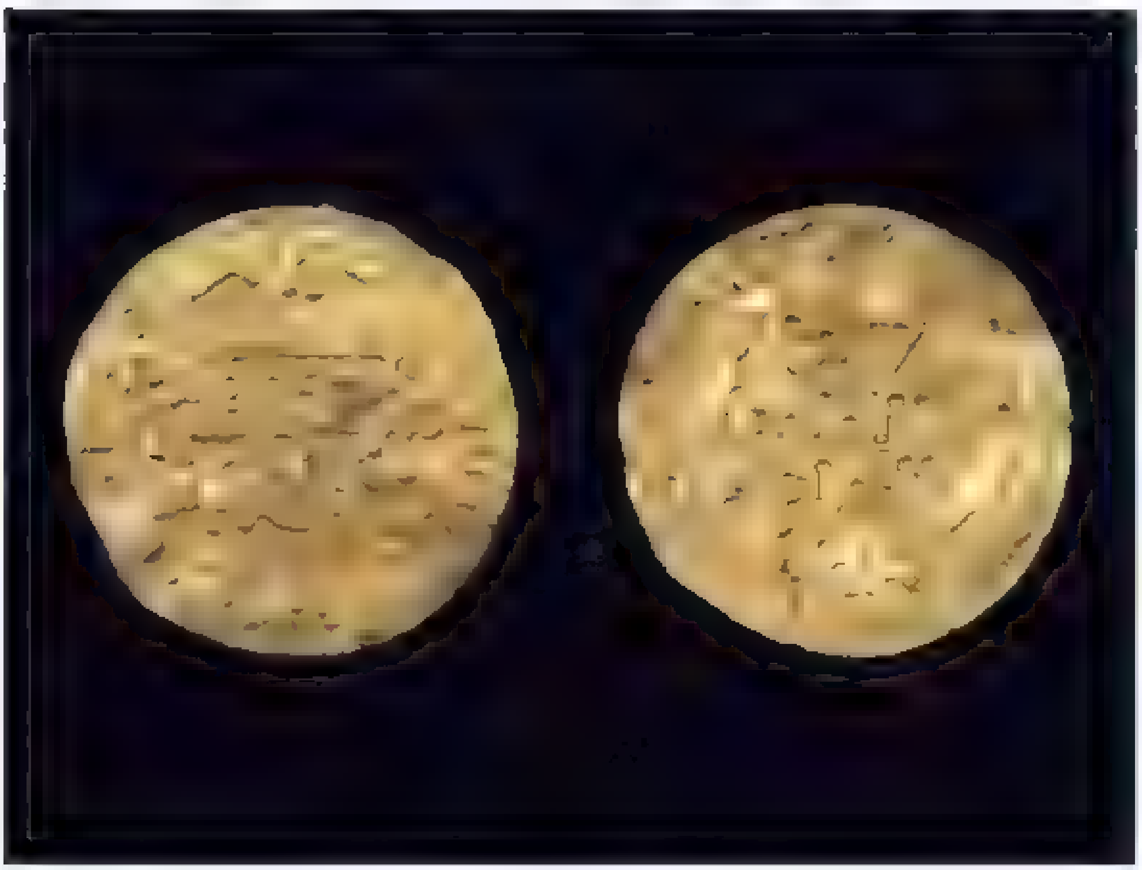
Archaeological discoveries have helped us to redraw the international economic and trade relations of twelve hundred years ago, when thousands of Muslim coins were found across Europe in Germany, Finland and Scandinavia.

An astounding coin was also discovered while digging in the UK, and it is now in the collection at the British Museum. The Gold Mancus was equivalent to thirty silver pennies, and the Anglo-Saxon King Offa, the king of Mercia and England, ordered it to be made in the 8th century. He also introduced silver coinage. What was extraordinary about the Gold Mancus was that it was a copy of a gold *dinar* of the Abbasid Caliph al-Mansur dated 157AH or 774 CE.

It is over twelve hundred and thirty years old, and has Arabic characters declaring that "There is no Deity but Allah, The One Without Equal, and Mohammad is the Apostle of Allah" and a further declaration engraved around the margin of the coin says, "Mohammad is the Apostle of Allah, Who sent him (Mohammad) with the doctrine and the true faith to prevail over every other religion."

A significant difference from the original *dinar* is that King Offa stamped his name on it with

King Offa of Mercia and England made a copy of [illegible]



Left to right: An 8th century map of the UK at the time when King Offa ruled England and Mercia; Charlemagne, the founder of the Holy Roman Empire, had a coin called a *denier* from the Arabic *dinar*, which was worth two-thirds of the *dirham*, the currency used in the Muslim world.

the inscription of OFFA REX. Scholars have puzzled about why an English king would have made a replica Arab coin. Some say he had converted to Islam, but the more likely story is that it was produced for trade, or for pilgrims to use as they travelled through Arab lands. The coin most certainly wouldn't have been made by an Arab craftsman because there isn't any understanding of the Arabic text. 'OFFA REX' is upside down in relation to the Arabic *Kufic* script, and the word 'year' is misspelled in Arabic. The coin was probably copied by Anglo-Saxon craftsmen.

Much of the evidence of the impact of Islamic trade and currency on Europe is found in the ground. The coins found show that Offa also introduced the silver penny and it was equivalent in weight and content to half the Abbasid *dirham*. Charlemagne's *denier*, or his reformed *denarius*, was worth two-thirds of the *dirham* and the Byzantine *miliaresion* was increased to the same weight and quality as the Arab *dirham*.

King Offa was not the only non-Muslim ruler to make an Arabic coin. An 11th-century Spanish Catholic prince, Alfonso VIII, ordered the minting of a decorative coin in which not only were the inscriptions written in Arabic, but also he referred to himself on the coin as the 'Ameer of the Catholics' and the Pope in Rome as the 'Imam of the Church of Christ'.

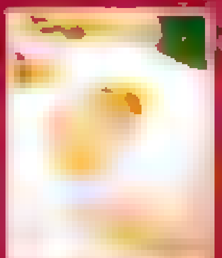
04 HOSPITAL

'Medicine is a science, from which one learns the states of the human body, with respect to what is healthy and what is not, in order to preserve good health when it exists, and restore it when it is lacking.'

10th-century Ibn Sina from his book *Canon*

[illegible]

The facilities they used [illegible] teaching hospital.



Hospital Development

THE IDEA BEHIND HOSPITALS A THOUSAND YEARS AGO was to provide a range of facilities from treatments to convalescence, asylum and retirement homes. They looked after all kinds of people, rich and poor, because Muslims are honour bound to provide treatment for the sick, whoever they may be.

From the earliest times, these hospitals were funded by charitable religious endowments, called *waqf*, though some money from the state coffers was also used for the maintenance of some hospitals. It was partly due to this funding they became strongholds of scientific medicine and an integral part of city life in less than two centuries.

Before the Muslims, the Greeks had temples of healing. In these, health care was based more on the idea of a miraculous cure rather than on scientific analysis and practice. A Byzantine charitable institution, the xenodocheion (literally 'places for strangers to lodge in'), came closest to being a hospital where care was given to the sick, lepers, invalids, and the poor.

Islamic hospitals began in 8th-century Baghdad and in some ways these resembled xenodocheions as they also looked after lepers, the invalid and the destitute. But the first organized 'proper' hospital was in Cairo built between 872 and 874 CE. The Ahmad ibn Tulun Hospital treated and gave medicine to all patients free of charge. With two bath houses, one for men and one for women, a rich library, and a section for the insane it was an incredibly advanced institution. Entering patients deposited their street clothes and their valuables with the hospital authorities for safe keeping, before donning special ward clothes and being assigned to their beds.

Two perspectives of Ibn Tulun Mosque, Cairo, Egypt, the first organized hospital that provided free treatments and medicines for patients.

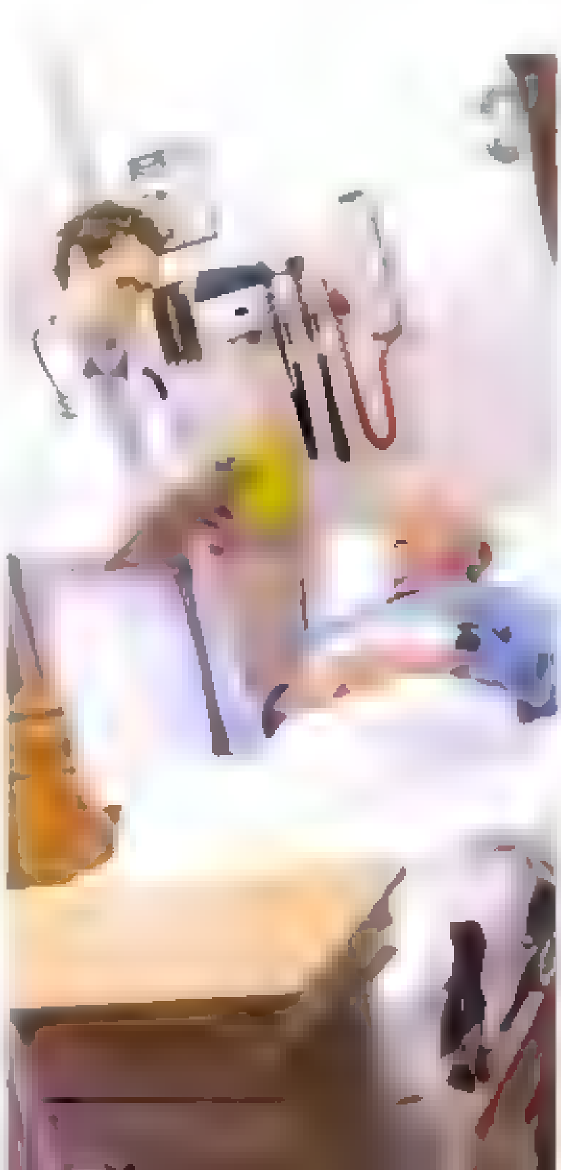
Other important hospitals included a larger Baghdadi Hospital, built in 982, with a staff of twenty-four physicians. Twelfth-century Damascus had an even larger hospital, the Nuri Hospital. Here, medical instruction was given and druggists, barbers, and orthopaedists, as well as oculists and physicians were, according to manuals composed in the 13th century, examined by 'market inspectors' on the basis of some set tests.

In all, Cairo had three immense hospitals, the most famous was the al-Mansuri Hospital. When the 13th-century Mamluk ruler of Egypt, Al-Mansur Qalawun, was still a prince, he fell ill with renal colic during a military expedition in Syria. The treatment he received in the Nuri Hospital of Damascus was so good that he vowed to found a similar institution as soon as he came to the throne. True to his word, he built the al-Mansuri Hospital of Cairo and said, 'I hereby devote these *waqfs* for the benefit of my equals and my inferiors, for the soldier and the prince, the large and the small, the free and the slave, for men and women.'

The 1284 al-Mansuri was built with four entrances, each having a fountain in the centre. The king made sure it was properly staffed with physicians and fully equipped for the care of the sick. He appointed male and female attendants to serve male and female patients who were housed in separate wards. Beds had mattresses and specialized areas were maintained. Running water was provided to all areas of the hospital. In one part of the building the physician-in-chief was given a room for teaching and lecturing. There were no limits to the number of patients that could be treated, and the in-house dispensary provided medicines for patients to take home.

From these early institutions, hospitals spread all over the Muslim world, reaching Andalusia in Spain, Sicily and North Africa. These were all admired by traders and crusaders, who later developed similar systems such as the Hospitaliers, fighters of the hospital, established by the French to treat their countrymen. In Europe, Muslim physicians helped in establishing scores of hospitals, including the famous Salerno hospital in southern Italy.

Muslims were effective administrators and hospitals were managed efficiently. For example, Ibn Jubayr, a 12th-century traveller, praised the way in which the al-Nuri Hospital (probably the earliest of its kind) managed the welfare of patients. He said 'The new one

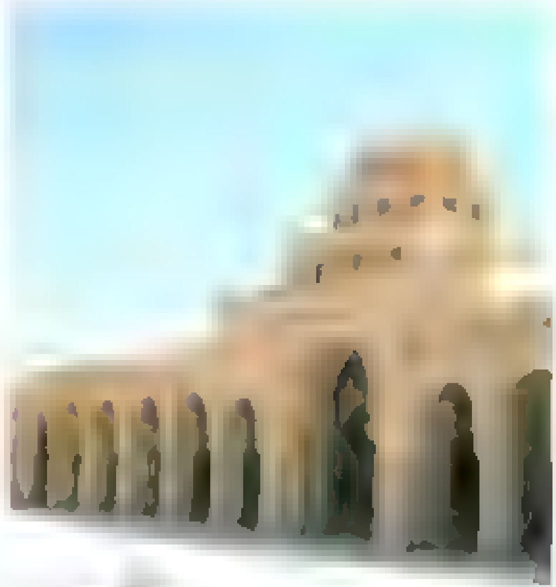


'It's [the hospital's] duty is to give care to the ill, poor, men and women until they recover. It is at the service of the powerful and the weak, the poor and the rich, of the subject and the prince, of the citizen and the brigand, without demand for any form of payment, but only for the sake of God, the provider.'

The constitution establishing the al-Mansuri Hospital, Cairo

Below left: The school of Salerno, from a 14th–15th century Latin translation of the manuscript *Canon of Medicine* by Ibn Sina.

The al-Qayrawan hospital in Qayrawan, Tunisia.



The 9th century al-Qayrawan hospital was a state-of-the-art [illegible] visitors, female nurses from Sudan, a mosque for patients to pray and [illegible] was deemed an untreatable sign of evil.

It was [illegible] gave generously to boost hospital income so that the best care could be provided.

[the Nuri Hospital] is the most frequented and largest of the two [hospitals in Damascus], and its daily budget is about 15 dinar. It has an overseer in whose hands is the maintenance of registers giving the names of the patients and the expenditures for the required medicaments, foodstuffs, and similar things. The physicians come early in the morning to examine the ill and to order the preparation of beneficial drugs and foods as are suitable for each patient.'

Whilst travelling in the Near East he also noted one or more hospitals in every city in the majority of the places he passed through, which prompted him to say that hospitals were one of 'the finest proofs of the glory of Islam'.

These hospitals were also forward-thinking, tackling ailments not only of the body. A 9th-century Baghdad hospital, where al-Razi worked, had an exclusive ward for the mentally ill.

Opposite: Exterior view of the present-day Sultan Qalawun, now a funerary complex. Earlier this site housed, in part, the al-Mansuri Hospital in Cairo, Egypt.

Teaching Hospitals

THE SIGHT OF A STREAM OF YOUNG and eager potential doctors behind a lofty surgeon is not an image new to the 21st century, as Muslims had university hospitals about eight hundred years ago. These teaching hospitals provided first hand practical and theoretical lessons for students.

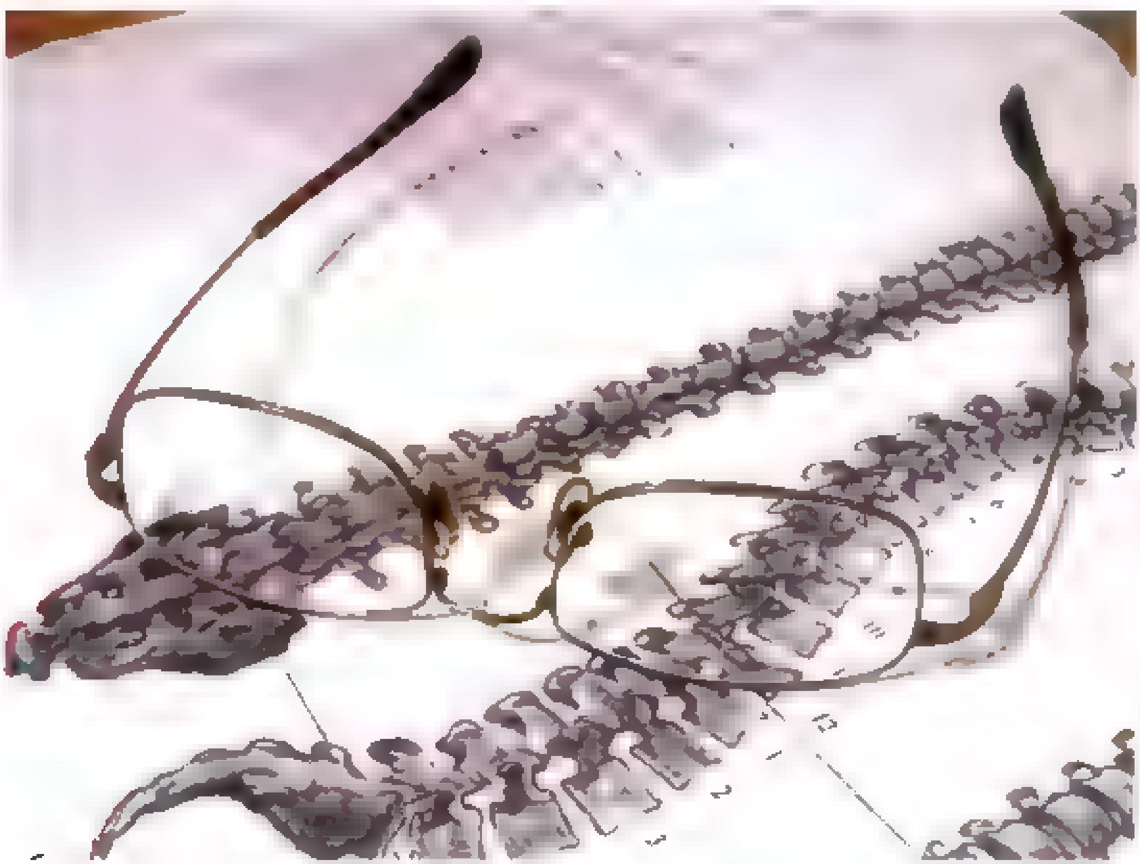
Teaching was done in both groups and on a one-to-one basis like today. Lectures were held in a large hall at the hospital and the subject matter was usually a reading from a medical manuscript by the so-called 'Reading-out Physician'. After the reading, the chief physician or surgeon asked and answered questions of the students.

Many students studied texts with well known physicians and, as paper was plentiful in the Muslim world, manuscripts have been preserved until today that have written on them 'for his own use'. In Europe these same texts were scarce and seldom owned by the student.

Bedside teaching, another part of medical training, with groups of students following the attending physician or surgeon on his ward rounds, was seen as very important. More advanced students observed the doctor taking the history of, and examining, patients and also making prescriptions for them in the Out-Patient Department of the hospital.

'Who so ever treats people without knowledge of medicine, becomes liable'.

Prophet Mohammad (pbuh) narrated by Al-Bukhari and Muslim



[illegible] A miniature showing an Ottoman chief physician; the entrance to the *Nur al-Din Bimaristan* or Hospital in Damascus, Syria. The hospital now houses the museum of Arab medicine and science.

'He who studies medicine without books sails an uncharted sea, but he who studies medicine without patients does not go to sea at all.'

William Osler,
Canadian Physician
(1849–1919)

One of these medical schools was in the al-Nuri hospital in Damascus. Under the direction of the physician Abu al-Majd al-Bahili, the 12th century ruler Nur al-Din ibn Zangi founded the hospital. It was named after him and he equipped it with supplies of food and medication, while also donating a large numbers of medical books, which were housed in a special hall.

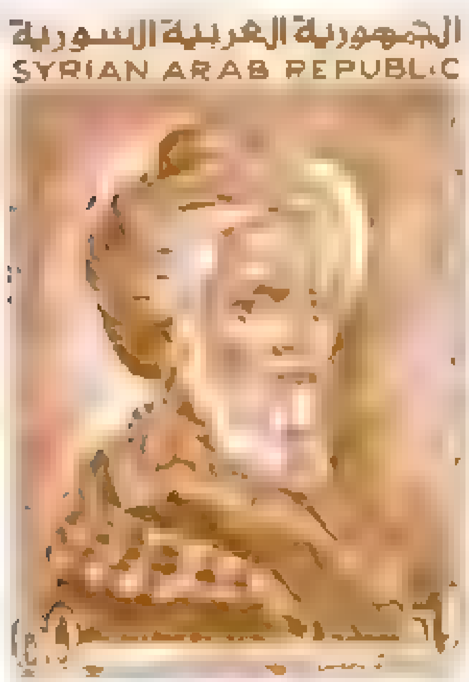
It was a place for a medical career to blossom. Early in the 13th century a physician called al-Dakhwar first served in the Nuri hospital at a low salary then, as he increased in fame, his income from private practice brought him much wealth and he started a medical school in the city. This career route will be familiar to many physicians today.

Many renowned physicians taught at the medical school, and physicians and practitioners sometimes assembled before the sultan, Nur al-Din, to discuss medical subjects. At other times they listened to the three-hour lectures that Abu al-Majd, the director of the hospital, gave his pupils. Among the well-known Muslim physicists who graduated from the medical school were Ibn Abi Usaybi'ah, a 13th century medical historian, and Ibn Nafis, whose discovery of the lesser circulation of the blood, also in the 13th century, marked a new step in better understanding human physiology.

Instruments of Perfection

YOU'RE IN A ROOM and someone brings in a tray with a cloth draped over it. This person sets down the tray and carefully peels back the cover to reveal twenty finely made but oddly shaped, metal tools. The person then says 'these are surgical instruments from hospitals today and from hospitals a thousand years ago. You have to separate them into two groups.' Could you do it? Maybe you're thinking 'Sure, that's easy. The thousand-year-old ones will be rough, crude, unsophisticated butcher's knives' – but read on before you decide.

If we journeyed back to 10th century southern Spain we could look over the shoulder of a cutting-edge surgeon called Abul Qasim Khalaf ibn al-Abbas al-Zahrawi, a man known in the West as Abulcasis. He would have already written *al-Tasrif*, his medical encyclopaedia, which you can read more about in the 'European Medicine' section in this chapter, and the 'Cleanliness' section in Home.



A 1964 Syrian commemorative stamp showing an artist's impression of the 10th century Spanish Muslim Surgeon al-Zahrawi.

Included in *al-Tasrif* was a treatise called *On Surgery*, which introduced a staggering collection of over two hundred surgical tools. Using instruments for surgery was a revolutionary concept because it enabled science to change from being speculative to experimental, and this was the first treatise in the history of medicine to illustrate surgical instruments. In fact, their design was so accurate that they have had only a few changes in a millennium, and it was these illustrations that laid the foundations for surgery in Europe.

The constant search for the perfect instrument for the sake of extreme accuracy became the rule with Muslim science, and is the principal rule of modern science today. In this search al-Zahrawi illustrated the instrument using clear hand-drawn sketches and also provided detailed information on how and when it was used.

For example, in cauterization he states that 'according to the opinion of the early (physicians) cauterization using gold is better than when using iron. In our opinion the use of iron is quicker and more correct.'

He wrote about the scraper (*majrad*) tool and its use when treating a fistula in the nose: 'Doctors give the name 'fistula' to what laymen call 'a quill'. When you have treated

it with cautery or with caustic according to the instructions given previously, and if it is not healed, there is no clear method of treatment except to cut down on the tumour at its ripening and let out all the humidity or pus therein, till you reach the bone. When the bone is reached and you see necrosis or blackness, scrape it with an instrument like this picture. It is called 'rough head' and is made of Indian iron. Its head is round like a button but is engraved with markings finely engraved, like those of a file or a rasp. Place it on the site of the diseased bone and spin it between your fingers, pressing down a little with your hand, till you are sure all the diseased bone has been scraped away. Do this several times. Then let the place be dressed with stanching and styptic remedies. And if the place heals and flesh is generated there and the flow of sanies [pus from a wound] is stayed and there is no return after leaving for forty days, and there is no swelling, and nothing emerges, you may know it is perfectly healed.'

The case of urethral stones was the subject of many pages of study. Al-Zahrawi devised an instrument *al-mishab* (the drill) for crushing these. He said, 'take a steel rod with a triangular sharp end ..., tie a thread proximal to the stone lest it slips back. Introduce it gently 'till it reaches the stone, turn it round to perforate it ... urine comes out immediately, press on the stone from outside and crush it by your finger, it breaks and comes out with urine. If you do not succeed then do cutting.'

Commenting on this, Lewis and Spink, recent translators of al-Zahrawi's book, described the originality of the instrument: 'This device of Abulcasis does seem to have been in a manner a true lithotripter [a stone crushing machine used to shatter kidney stones and gallstones] many centuries earlier than the modern era and completely lost sight of and not even mentioned by the great middle era surgeons

'Al-Zahrawi remains a leading scholar who transformed surgery into an independent science based on the knowledge of anatomy. His illustration and drawing of the tools is an innovation that keeps his contribution alive, reflected in its continuous influence on the works of those who came after him.'

L Leclerc, 19th-century French medical historian

A 1532 woodcut showing cauterization which ... work by al-Zahrawi, also known as Abulcasis, in the Latin translation by Gerard of Cremona

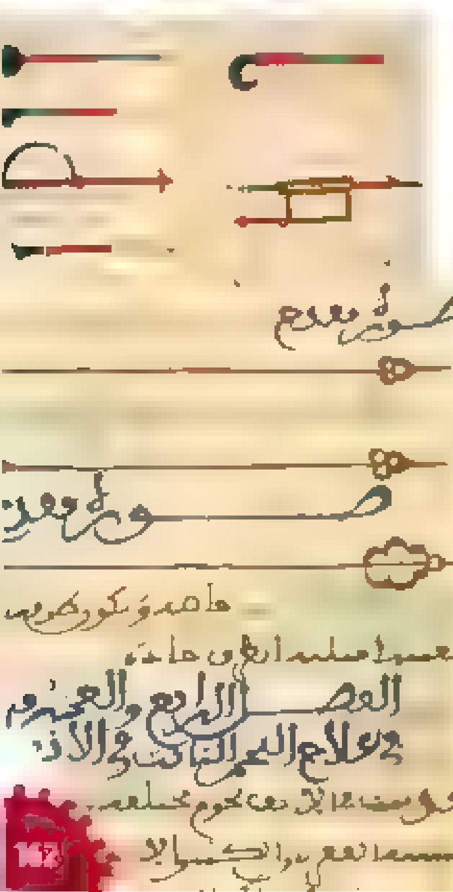
Franco and Paré nor by Frère Cômethe, doyen of genito-urinary surgery.'

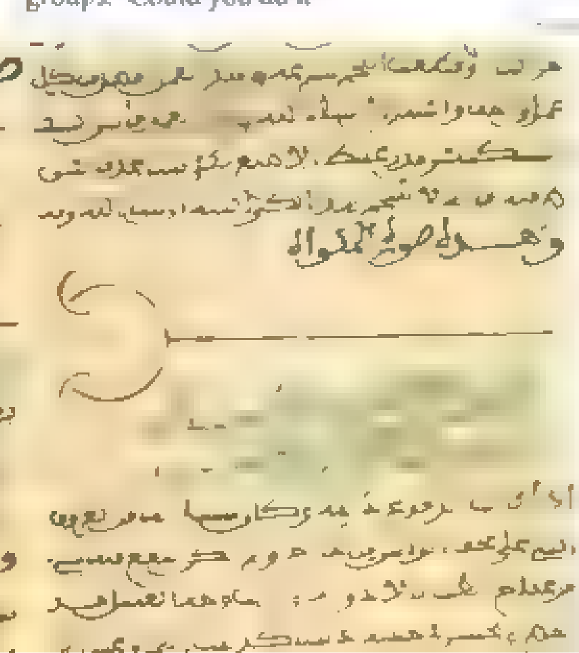
Ibn Zuhr, a 12th century Seville physician improved on this device by fixing a diamond at the end of the steel rod. As well as drills, al-Zahrawi also manufactured a knife to perform cystolithotomy.

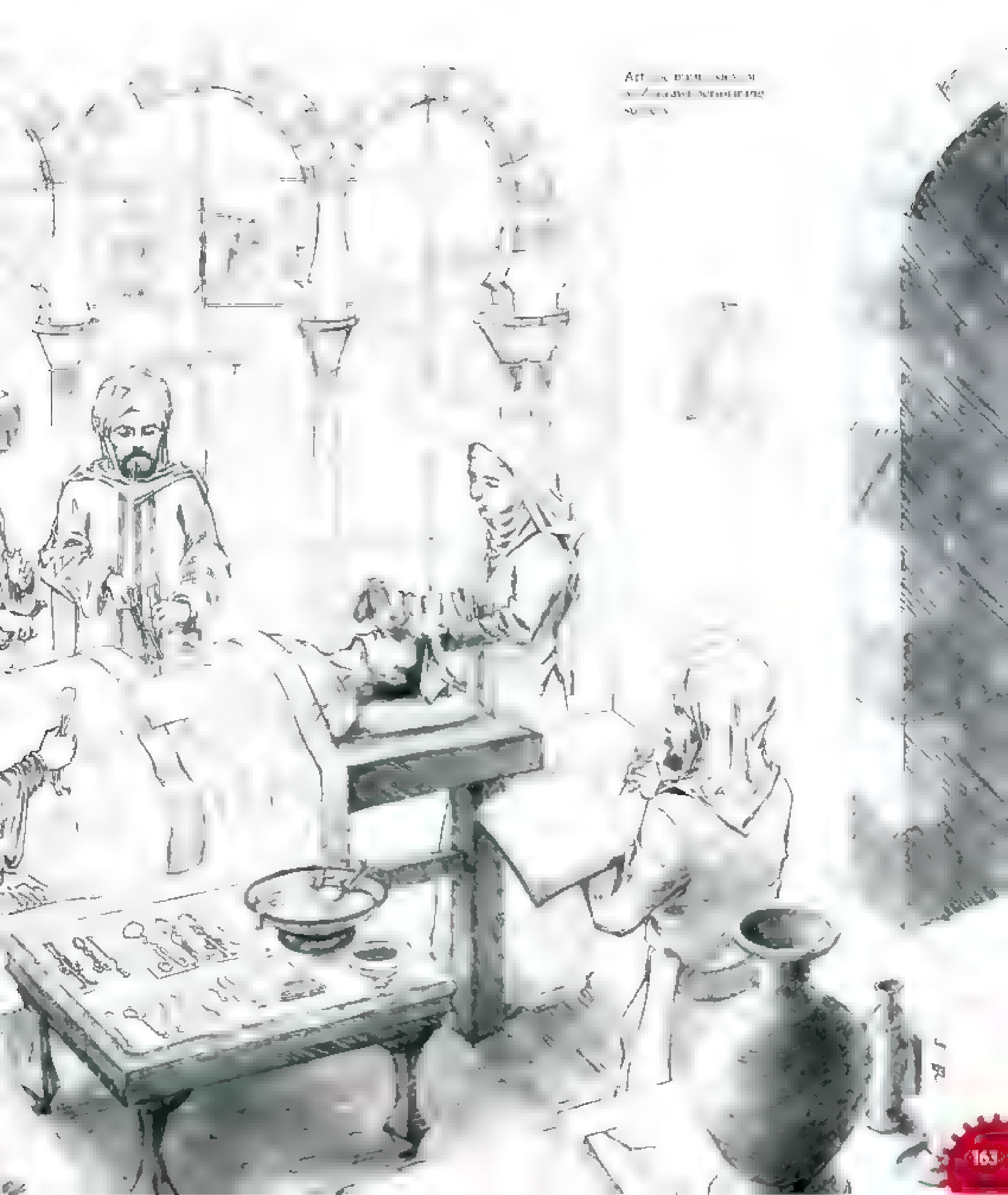
Other instruments discussed by al-Zahrawi include cauterization tools of various shapes and sizes; scalpels, very sharp knives that are used for making a variety of incisions; hooks, usually with a sharp or blunt half-circular end that are still used and named in the same way (blunt hooks were inserted in the veins to clear blood clots, sharp hooks were used to hold and lift small pieces of tissue so that they could be extracted and to retract the edges of wounds); forceps, metal instruments with two handles used in medical operations for picking up, pulling and holding tissue (crushing forceps used two jaws for crushing and removing urinary bladder stones; delivery forceps had a semi-circular end designed to pull the foetus from its mother, an instrument still used today).

Remember what was asked earlier: "The person then says "these are surgical instruments from hospitals today and from hospitals a thousand years ago. You have to separate them into two groups." Could you do it?'

Below: A manuscript describing surgical instruments by al-Zahrawi: saws (Minshar) of various shapes and scalpels (Mibda') used in orthopaedic surgery.







Art [illegible]

Surgery

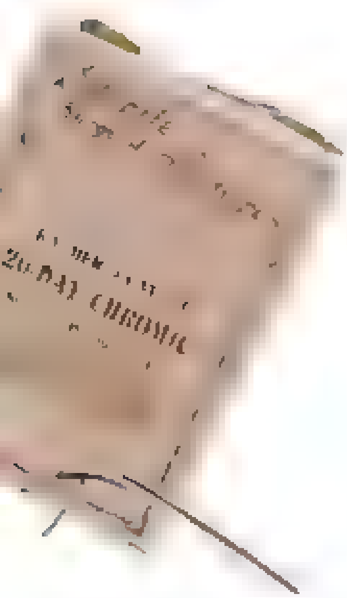
MODERN SURGERY is a highly sophisticated culmination of centuries of innovation by dedicated people bent on saving lives. This life-saving ethic was beating in the heart of Muslim southern Spain a thousand years ago, where the Muslims performed three types of surgery: vascular, general and orthopaedic.

One of the most famous Muslim surgeons at this time lived in Cordoba at the height of Islamic civilization. Abul Qasim Khalaf ibn al-Abbas al-Zahrawi, was known in the West as Abulcasis and you can read more about his work throughout this Hospital chapter. He observed, thought, practised and responded to each of his patients with skill and ingenuity. So much so that he was recognized in his day as an eminent surgeon and was court physician to the ruler of al-Andalus, al-Mansur.

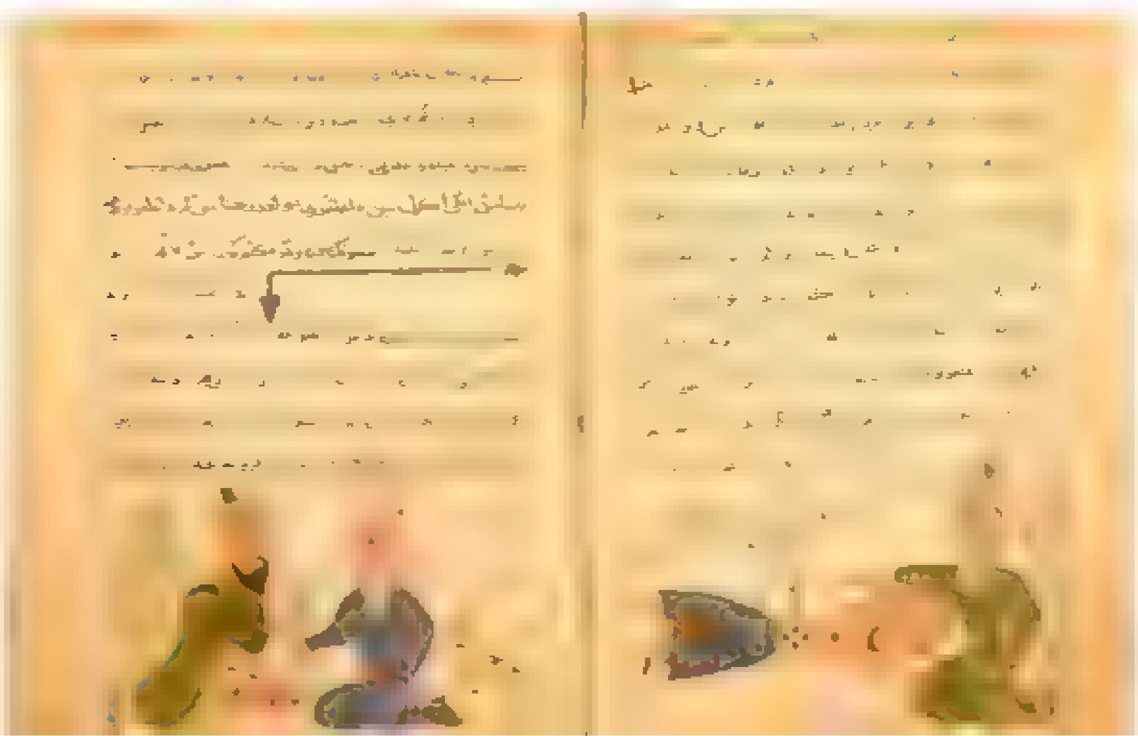
He revolutionized surgery by introducing new procedures, over two hundred surgical instruments, and giving detailed accounts of the full dental, pharmaceutical, and surgical disciplines of his time. His book, *al-Tasrif*, also established the rules of practical medicine by emphasizing the dos and don'ts in almost every medical situation encountered.

Al-Zahrawi has a list of firsts to his name and reading his curriculum vitae is impressive to read. New procedures he introduced included catgut for internal stitching, which is still used in the simplest to the most complicated surgery today. Catgut seems to be the only natural substance capable of dissolving and being accepted by the body.

Although al-Zahrawi was the first to use catgut in surgery, it was al-Razi who was the first to



Below right and overleaf: 15th-century miniatures in Serefeddin Sabuncuoglu's [illegible] illustrating the treatment of patients and showing various surgical procedures. Serefeddin Sabuncuoglu was a physician [illegible] Turkey.



use animal (sheep) gut for sutures, and Al-Zahrawi also used twisted fibres from strings of musical instruments for surgical purposes.

Responding to each case with ingenuity, he revolutionized medical procedures in many ways like using bone replacement for lost teeth; describing how to connect sound teeth to those that were loose by gold or silver wire; introducing a surgical treatment for sagging breasts; being the first to use cotton to control bleeding; performing a tracheotomy; regularly using plaster casts; and for calculus in the urethra, he introduced the technique of using a fine drill inserted through the urinary passage.

He also detailed how to remove a urinary bladder stone after crushing it with a self-designed instrument. He discussed simple surgery like nose polyp removal and complicated procedures like the removal of a dead baby using special forceps he devised himself. He mentions cauterizing or burning the skin to relieve pain and how to correct shoulder dislocation.

With all his innovations he kept his patients in mind, and in order not to frighten them in his surgical operations, he invented a concealed knife to open abscesses. In the case of tonsillectomies, he held the tongue with a tongue depressor, and then removed the swollen tonsil holding it with a hook and snipping it off with a scissor-like instrument. This had transverse blades which cut the gland and held it for removal from the throat so the patient didn't choke.

Al-Zahrawi, like all Muslim surgeons, displayed a sensible and humane reluctance to undertake the riskiest and most painful operations like all Muslim surgeons, as they were aware of the discomfort they inflicted on patients. This was a decisive breakthrough in the relationship between the surgeon and the patient.

Al-Zahrawi devoted Chapters 60 and 61 of his surgery book to the topic of performing a transvaginal cystolithotomy, the removal of stones. *On Surgery* was only one of the thirty books to

Modern surgical tools and catgut do not differ much from those invented by al-Zahrawi.

make up *al-Tasrif*, so this makes you appreciate the amount of work he did.

He also described the operation to remove bladder stones, or 'The Lesser Operation', *Apparatus Minor* as it was called in the Middle Ages, and this was similar to the one in the *Sushruta Samhita* in Hindu Medicine. Both al-Razi and al-Zahrawi stressed that the inner incision should be smaller than the external one to prevent leakage of urine. The stones should not be pulled out but extracted by forceps, and big ones should be broken and then delivered out bit by bit. This demonstrates their care to avoid damage to the tissues, excessive bleeding and formation of any urinary fistula. Al-Zahrawi also said every piece should be removed because even if one is left it will increase in size. This advice is still stressed nowadays.

'Surgeons must be very careful When they take the knife! Underneath their fine incisions Stirs the Culprit - Life!'

Emily Dickinson

Right: 15th century miniatures in Serefeddin Sabuncuoglu's *Jarrahiyat al-Khaniyyah* illustrating the treatment of patients and showing various surgical procedures. Serefeddin Sabuncuoglu was a physician from Amasya, Turkey.

In gynaecology, his work, along with that of other Muslim surgeons, was pioneering. He gave instructions for training midwives on how to perform unusual deliveries and remove the afterbirth. He also designed and introduced vaginal dilaters.

Ibn al-Quff, a 13th-century Syrian physician, pointed out the difficulty of surgery in a woman 'because she may be a virgin, or shy, and a finger cannot be pushed into her vagina in search of the stone, or a big incision may be needed . . . and that is dangerous, or she may be pregnant and surgery will endanger her pregnancy.'

As well as al-Zahrawi, there were many surgeons in Islam who carried out ground-breaking work, including Ibn Sina in the 11th century, who was from present-day Uzbekistan. He wrote *Canon* which addressed the breadth of medicine, and you can read more about him in 'Bone Fractures.'

In the opinion of Ibn Sina, cancer, *al-sartan* in Arabic, was a cold tumour that did not get inflamed, and was painless at first. Certain forms became painful and often incurable when they reached an advanced level. He said cancer grew out of the centre just like the legs of a crab, from which it took its name. The internal cancers appeared without the patient's awareness, and despite their pain, patients could live quite long with them. The only forms of cancer upon which the surgeon could intervene were the 'limited cancers.' Here, the incision had to be perfect, so all of the tumour would be extracted. However, surgery was not always conclusive and definite, for the cancer could often reappear. Ibn Sina, in fact, advised against the amputation of the female breast, for it favoured the spread of the disease. He then pointed out that oxide of copper or lead, although unable to cure the disease, could be efficient in stopping the spread of the cancer.

Ibn Sina, like al-Zahrawi, spoke on many topics. On the retention of bladder stones he explained: 'If the patient lies on his back and his buttocks are raised and he was shaken, the stone moves away from the passageway, urine streams out, it may also be easy to push away the stone by a finger in the rectum . . . If that does not work, use a catheter to push the stone back . . . If it was difficult to be passed do not push hard.' This is quite similar to how modern urologists handle an obstructing posterior urethral stone. They push it back either by a catheter or endoscopically.

According to Ibn al-Quff, surgical treatment of large bladder stones was easier than that of small ones because the large ones either stopped in the urethra or were in the cavity of the bladder, and here they could be more easily felt.

From all this evidence we can see that a thousand years ago ailing people were treated in hospitals and looked after incredibly well. Unlike today we do not have survival rates or statistics of success, but we do have copious notes from the great surgeons of the time. These notes of practices and research changed surgery irreversibly, for the better of all, even us in the 21st century.

Blood Circulation

THE HISTORY OF THE DISCOVERY of how blood travelled round the body is as intricate as the veins and arteries carrying it. The ancient Greeks thought that the liver was the origin of the blood, believing food reached the liver from the intestines through the veins. In the liver, blood would be filled with 'natural spirit' before it continued the journey to the right heart ventricle, and then to the rest of the body parts.

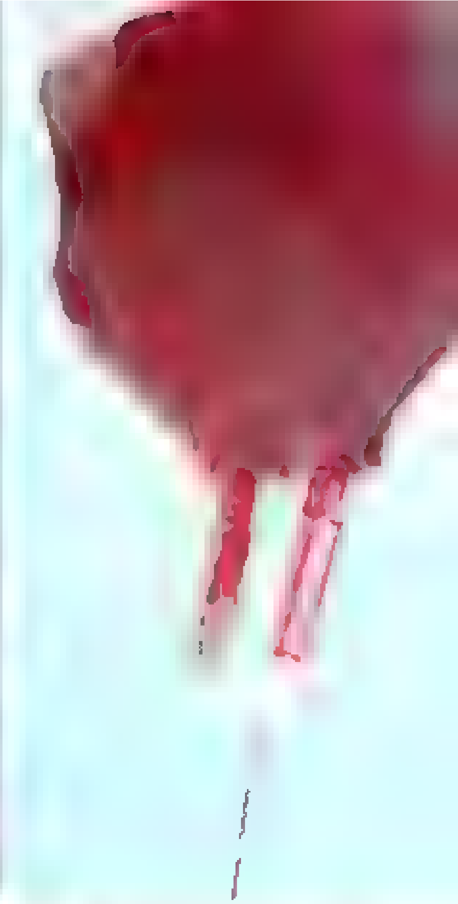
Then Galen, a Greek physician and scholar in the 2nd century CE, made further observations. He said that the blood reaching the right side of the heart went through invisible pores in the cardiac septum to the left side of the heart. Here it mixed with air to create spirit and was then distributed to the body. According to his views, the venous system was quite separate from the arterial system, except when they came in contact by small unseen 'shunts' or channels.

For centuries, this explanation was accepted as the truth until the story of discovery re-emerged in 16th century Europe, when William Harvey made groundbreaking research into the circulation of the blood and the function of the heart. Harvey argued that the heart was at the centre of the circulatory system, and he was known as the person who discovered how our blood travels round our bodies.

Well, that's one story, because in 1924 a very important manuscript was unearthed and made known to the world by an Egyptian physician, Dr Muhyo al-Deen Altawi. He discovered a seven-hundred-year-old treatise entitled, *Commentary on the Anatomy of the Canon of Avicenna* in the Prussian state library in Berlin. He was researching the history of Arab Medicine at the medical faculty of Albert Ludwig University in Germany. This discovery revealed an important scientific fact, which up to then had been ignored: the first description of the pulmonary circulation.

The manuscript *Commentary on the Anatomy of the Canon of Avicenna* was written by Ibn Nafis, a Muslim scholar born in Damascus, Syria in 1210 CE and educated at the famous Nuri Hospital. When he 'graduated' he was invited to Cairo by the sultan of Egypt to work as the Principal of the Nasiri Hospital, founded by Saladin in Cairo.

[illegible] the work of Galen. Note that it was only [illegible] that we could find the work of Greek scholars like Galen. They were translated back into Latin and Greek in later [illegible]



Above left: An 1848 painting of William Harvey (1578-1657) demonstrating to Charles I his theory of the circulation of the blood

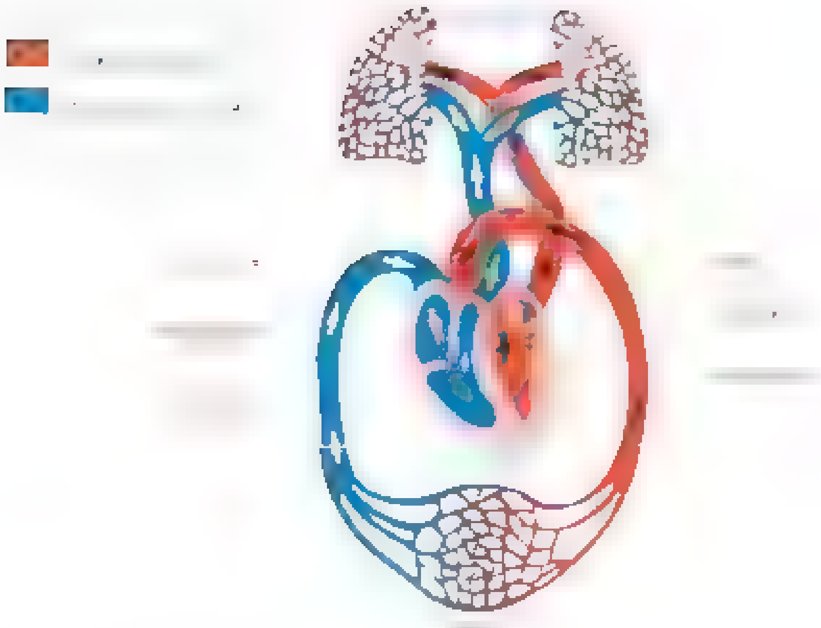
As well as having a busy professional career as a physician and leading authority, Ibn Nafis wrote a number of books on a variety of subjects which has helped develop knowledge. These books included *Book of Selected (Healthy) Food* and *Medical Encyclopaedia*, but his big work was *Commentary on the Anatomy of the Canon of Avicenna*.

Commentary on the Anatomy of the Canon of Avicenna was a discussion of the work of another intellectual giant, Ibn Sina, otherwise known as 'Avicenna.' Avicenna was born in 980 CE in a small village in an area that is now southern Russia. He was a polymath who excelled in philosophy, law and medicine. Ibn Nafis's own treatise was responding to Avicenna's monumental work called *Canon* for short, which you can read more about in the section on Bone Fractures.

Ibn Nafis's commentary was so famous because he accurately studied and described the pulmonary circulation. In it he explained the role of the heart and lungs, in effect the respiratory system, emphasizing that blood was purified in the lungs, where it was refined on contact with the air inhaled from the outer atmosphere.

In one paragraph, he describes the anatomy of the heart and disagrees with Ibn Sina: "The opinion of Ibn Sina that the heart has three ventricles is not correct. The heart has only two ventricles [illegible] and between these two there is absolutely no opening. Also dissection gives this lie to what they said, as the septum between these two cavities is much thicker than elsewhere. The benefit of this blood (that is, in the right cavity) is to go up to the lungs, mix with what is in the lungs of air, and then pass through the pulmonary vein to the left cavity of the two cavities of the heart [illegible]"

On how the blood's pulmonary circulatory system worked, Ibn Nafis explained that the system was based on the movement of blood from one chamber of the heart to the lungs



The blood circulation system. In the 13th century, Ibn Nafis explained the pulmonary blood circulation system, i.e. the system of oxygenation of oxygen-poor blood by the lungs. The right ventricle of the heart pumps deoxygenated blood to the lungs through the pulmonary arteries where it is oxygenated and then returns to the left atrium of the heart through the pulmonary veins. In the 17th century William Harvey discovered the full blood circulatory system in which the blood returns to the heart from the body extremities (the blue arrows to the heart in the diagram)

and then back to a different chamber of the heart. According to him, nutritive blood produced by the liver was distributed through the veins to all the organs and peripheral parts of the body, while blood enhanced with vital pneuma (air from the lungs) flowed through the arteries to all parts of the body. His innovation was to say that the venous blood from the right ventricle of the heart (to be enhanced with air from the lungs) had to pass through the lungs before entering the left ventricle, at which point it could enter the arteries as arterial blood.

In his own words he said: "… the blood from the right chamber of the heart must arrive at the left chamber, but there is no direct pathway between them. The thick septum of the heart is not perforated and does not have visible pores as some people thought or invisible pores as Galen thought. The blood from the right chamber must flow through the pulmonary artery to the lungs, spread through its substance, be mingled with air, pass through the pulmonary vein to reach the left chamber of the heart."

In modern language, this is translated as follows: Blood that has waste in it comes into the right atrium through the large vein called the vena cava. Filled with this waste-rich blood, the right atrium then contracts, pushing the blood through a one-way valve into the right ventricle. In turn the right ventricle fills and contracts, sending the blood into the pulmonary artery which connects with the lungs. There, in the capillaries, the exchange of carbon dioxide and oxygen takes place. The blood is now oxygen-rich as it enters the pulmonary veins, returning to the heart via the left atrium. The left atrium fills and contracts, pushing oxygen-rich blood through a one-way valve into the left ventricle. The left ventricle contracts, forcing the blood into the aorta from which its journey throughout the body begins.

These important observations were not known in Europe until three hundred years later when Andrea Alpago of Bellano translated some of Ibn Nafis' writings into Latin in 1547. Following this, a number of attempts were made to explain the phenomenon, including by Michael Servetus in his book Christianismi Restitutio in 1553 and Realdus Colombo in his book De re Anatomica in 1559. Finally it was Sir William Harvey, in 1628, who was credited with for the discovery of the, whilst Ibn Nafis remained as the pioneer of the 'lesser', or 'pulmonary', circulation.

It was only in 1957 that Ibn Nafis was credited with the discovery. He had died less than seven hundred years earlier in 1288 CE after donating his house and library to the recently constructed al-Mansuri Hospital in Cairo.

Ibn Sina's Bone Fractures

Ibn Sina, known as Avicenna in the west, was so highly regarded that he was compared to Galen, the ancient Greek physician, and he was known as the 'Galen of Islam'. Because of his great celebrity, many nations competed to celebrate his anniversary, with Turkey being the first in 1937, nine hundred years after his death.

To appreciate his contribution in developing the philosophical and medical sciences, all members of UNESCO celebrated a thousand years after his birth in 1980.

He was born in Afshana, now in Uzbekistan, and left aged twenty-one, spending the rest of his life in various Persian towns, becoming a renowned philosopher and medic. Through his life he composed 276 works, all written in Arabic, except for a few small books written in his mother tongue, Persian. Unfortunately, most of these works have been lost, but there are still sixty-eight books or treatises available in eastern and western libraries.

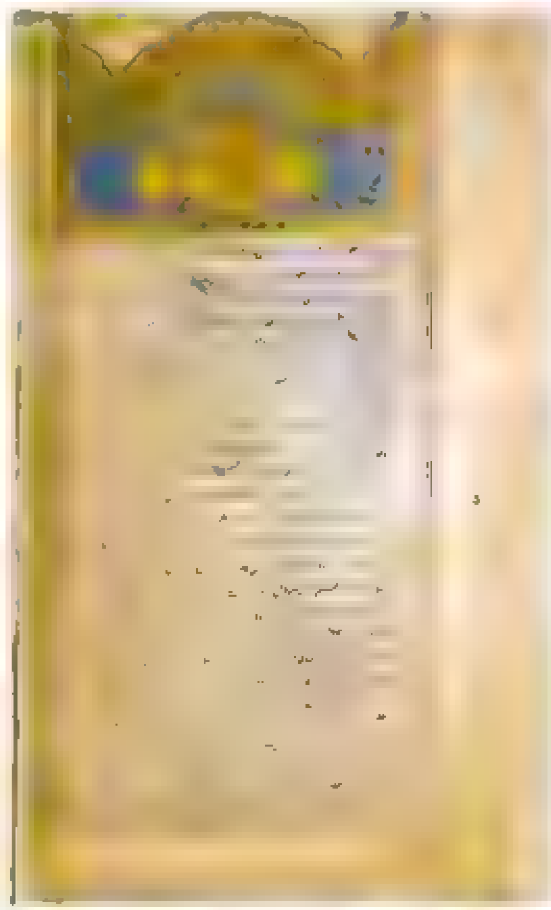
He wrote in all branches of science, but he was most interested in philosophy and medicine, so some recent historians called him a philosopher more than a physician, but others say he was the 'Prince of the Physicians' during the Middle Ages.

The majority of his work was in medicine. Forty-three works were in this area; twenty-four in philosophy; twenty-six in physics; thirty-one in theology; twenty-three in psychology; fifteen in mathematics; twenty-two in logic; and five in Quran interpretation. He also wrote on asceticism, love and music, and he wrote some stories.

Al-Qanun fi al-Tibb or *Code of Laws in Medicine* was his most important work, and is known in English as the *Canon*. It was written in Arabic, and has been described as the most famous medical textbook ever written, because it is a unique reference full of all medical knowledge gathered from many civilizations until his time.

'Anyone who wants to be a good doctor must be an Avicennist.'

Old European common saying



[illegible] the first book of *The Canon* [illegible] Ibn Sina [illegible] and [illegible] Prophet Muhammad [illegible] and companions.

By the 12th century the essentials of the *Canon* were condensed to make the ideas more readily accessible, and commentaries were written to clarify the contents. The most popular short version was called *The Concise Book in Medicine*, written in Syria by Ibn Nafis, who died in 1288.

The *Canon* was made up of five books. The first was concerned with general medical principles, the second with materia medica, the third with diseases occurring in a particular part of the body, the fourth with diseases not specific to one bodily part, like fevers and also traumatic injuries such as fractures and dislocations of bones and joints. The final book contained a formula giving recipes for compound remedies.

The fourth book about fractures had two treatises: one was called 'Fractures as a Whole' and the second was 'Fractures of Every Bone Separately'.

'Fractures as a Whole' described the causes, types, forms, methods of treatment, and complications of fractures, talking about fractures in general, while 'Fractures of Every Bone Separately' looked at the special characteristics of fractures of each bone. Ibn Sina, by using this form of explanation, was very close to following the format of modern medical textbooks.

He drew attention to the necessity of not splinting the fracture immediately, advising postponing it beyond the fifth day. Today, this is called the 'Theory of Delayed Splintage' and now Professor George Perkins is considered the pioneer of this theory.

Ibn Sina talked about what is now called 'Bennett's fracture (1882)' a thousand years before Bennett.

The arrangement, comprehensiveness and methods of explanation of the *Canon* were very close to the layout of modern medical textbooks with regard to classification, causes of diseases, epidemiology, symptoms and signs, and treatment and prognosis. This made the *Canon* the most widely used medical book in both Muslim and European countries, and it was known to Europeans in the 12th-century Latin translations of Gerard of Cremona. It remained in use in medical schools at Louvain and Montpellier until the 17th century, and according to the Journal of UNESCO it was still in use at Brussels University until 1909, well into the age of 'modern medicine'.

'Medicine was absent until Hippocrates created it, dead until Galen revived it, dispersed until Rhazes (al-Razi) collected it, and deficient until Avicenna (Ibn Sina) completed it.'

Dr. Poure, European physician

Cover of the Latin edition of [illegible]

Notebook of the Oculist

NEARLY EVERY MEDICAL BOOK by Muslims a thousand years ago covered some aspect of eye diseases. Their studies were limited only because animal eyes were used instead of human eyes, because the dissection of the human body was considered disrespectful in principle. However, that didn't stop the oldest pictures of the anatomy of the eye from being constructed.

Muslim eye surgeons or ophthalmologists of the 10th to the 13th centuries were performing operations, dissecting, discovering and writing about their findings in textbooks and monographs. According to Professor Hirschberg, an eminent 20th-century German Professor of Medicine, thirty ophthalmology textbooks were produced, and fourteen of them still exist today.

Modern terms were used like conjunctiva, cornea, uvea and retina. Operations on diseases of the lids like trachoma, a hardening of the inside of the lid, were also common practice. The treatment of glaucoma, an increase in the intraocular pressure of the eye, under the name of 'headache of the pupil' was popular, but the greatest single contribution to ophthalmology by the Muslims was in the treatment of cataracts.

The term for cataract in Arabic is *al-ma' nazil ayn*. *Ma* means water or water descending onto the eye, which is the water accumulating in the lens, making it soggy and cloudy.

To restore vision, al-Mawsili, from 10th century Iraq, designed a hollow needle and inserted it through the limbus, where the cornea joins the conjunctiva, to remove the

cataract by suction. This type of cataract operation, among others, is still carried out today with some added modern techniques, such as freezing the lens before suction.

From his study and practice he then wrote the *Book of Choices in the Treatment of Eye Diseases*, which discussed forty-eight diseases. This manuscript (No. 894) can be found in the Escorial Library in Madrid, Spain.

Until the 20th century, al-Mawsili's work was only available in Arabic and a 13th-century Hebrew translation. The German version was made as recently as 1905 by Professor Hirschberg who wrote that al-Mawsili was, 'The most clever eye surgeon of the whole Arabian Literature.'

A contemporary of al-Mawsili and the most famous of all the oculists of Islam was Ali ibn Isa, also from 10th-century Baghdad, Iraq. He wrote the *Notebook of the Oculist* and this was the most complete text book on eye diseases which was translated into Latin, and printed in Venice in 1497. Again Professor Hirschberg and his fellow eye surgeon Lippert translated it into German in 1904, and the English version, by American oculist and academic Casey Wood, appeared in 1936.

Ibn Isa's book *Notebook of the Oculist*, was the authoritative textbook on ophthalmology for centuries, describing 130 eye diseases, including several forms of trachoma and ophthalmia.

It is also the oldest Muslim work on ophthalmology that is complete and survives in the original state. Dr Cyril Elgood, a 20th-century British medical historian, wrote: 'The first part is devoted to anatomy, the second to

'During this total darkness in medieval Europe they [the Muslims] lighted and fed the lamps of our science [ophthalmology] - from the Guadalquivir [in Spain] to the Nile [in Egypt] and to the river Oxus [in Russia]. They were the only masters of ophthalmology in medieval Europe.'

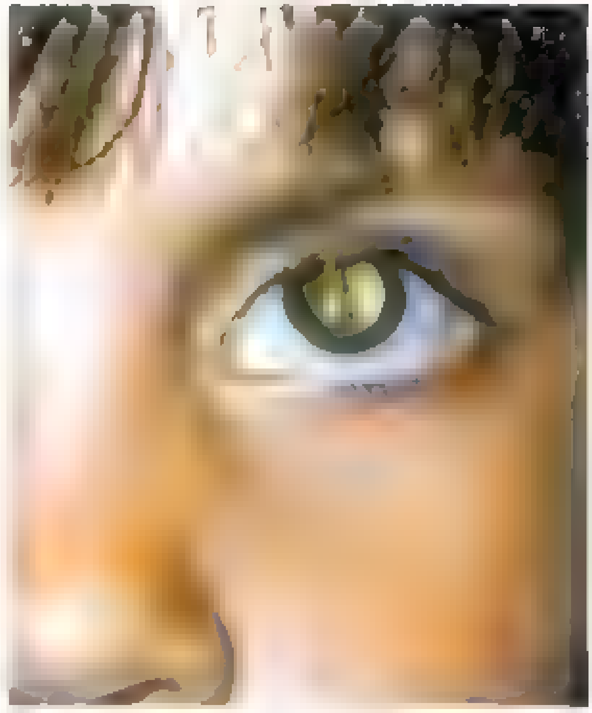
Professor J Hirschberg concludes his address to the American Medical Association, July 1905

The anatomy of the eye from a 12th-century manuscript referring to the treatise on ophthalmology by Hunayn ibn Ishaq, a 9th-century Christian from Baghdad. Note that during Muslim civilization, Muslim and non-Muslim scholars worked side by side. There was no prejudice.

Muhammad ibn Qassum ibn Aslam al-Ghafiqi's book, 'The Right Guide in Ophthalmic Drug' ... is not just confined to the eye but gives details of the head and diseases of the brain.

'Muslim physicians have been in the forefront of the effort to prevent blindness since 1000 CE, when al-Razi became the first doctor to describe the reflex action of the pupil. At about the same time, ... al-Mawsili invented the technique of suction removal of cataracts by the use of a hollow needle.'

Optometry Today, publication of the Association of Optometrists, England, March 28, 1987



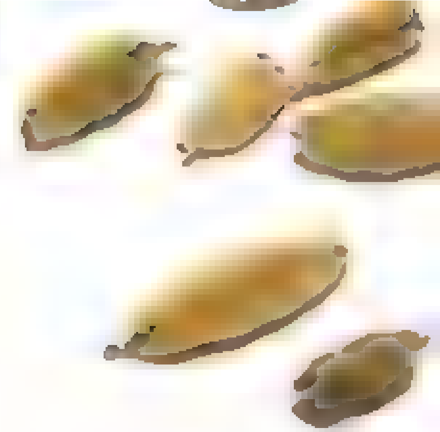
the external diseases of the eye, and the third part to internal diseases of the eye which are not visible upon inspection. ... The nearest approach that Ali makes to the modern conception of eye disease as a manifestation of general disease is when he urges the practitioner to realize that defective vision may be due to a disease of the stomach or brain just as much as to an incipient cataract.'

Ibn Isa was not the only eye surgeon to urge that diseases of the eye were a sign of other ailments. Abu Ruh Muhammad ibn Mansur ibn Abdullah, known as al-Jurjani, from Persia around 1088, wrote a book called *The Light of the Eyes*. One chapter dealt with diseases that lay hidden, but whose signs were clear in the eyes and vision, like third nerve paralysis, blood disorders and toxicity.

An oculist who has been immortalized in a bust in Cordoba, southern Spain, is Muhammad ibn Qassum ibn Aslam al-Ghafiqi. He lived and practised in Cordoba, writing a book called *The Right Guide in Ophthalmic Drug*. The book is not just confined to the eye but gives details of the head and diseases of the brain. Reporter Rageh Omar said in the BBC's *An Islamic History of Europe* that al-Ghafiqi's treatment of the eye disease trachoma was carried out until World War I. His bust is in the municipal hospital of Cordoba and was erected in 1965 to commemorate the 800th anniversary of his death.

In the United Kingdom today, cataracts are the most common cause of blindness in people over fifty, but there's good news from the Royal College of Ophthalmologists who say that 'Cataract surgery has excellent outcomes and makes an enormous difference to patients' lives. Over three hundred thousand cataract operations were undertaken by NHS staff in England last year [2005], making it the most commonly performed elective operation in the country.' Who would have thought that al-Mawsili's work in the 10th century would have laid the foundations for an incredibly popular 21st century surgery?

Cataract removal operation has not changed much from the times of al-Mawsili.



Left: Different botanical species from a treatise by Ibn al-Baytar of Malaga, 13th century, giving the physiology of plants and descriptions of their sowing environment as well as their maintenance. The left is from the manuscript *al-Kafi* and the right from the manuscript *al-Filaha*.

Ibn Samajun, who died in 1002, wrote *Collection of Simples, Medicinal Plants and Resulting Medicines*. This was a classification of plants and their medical properties based on the work of his predecessors. Also in the 11th century, Ibn Sina in his *Canon* listed 142 properties of herbal remedies.

Botany, the scientific study of plants, and the use of plants in medicine went hand in hand. While men like Abu Hanifa al-Dinawari, called 'the father of modern botany', were compiling vast lists of plants in books like his *A Treatise on Plants*, others, like al-Razi, a 10th century medical scholar, used colchicum as a drug for the treatment of gout.

As botany became an academic science, chemistry was advancing at an incredible rate, and both these developments helped to propel herbal medicine into the mainstream. Coupled with the appearance of improved water raising machines and new irrigation techniques in the 10th century, experimental gardens sprouted and herbs were cultivated.

Al-Andalus or Muslim Spain was a springboard for herbal development. In 11th century Toledo, Spain, and later in Seville, the first royal botanical gardens of Europe made their appearance. Initially they were pleasure gardens, but they also functioned as trial grounds for the acclimatization of plants brought from the Near and Middle East.

You can read about Ibn al-Baytar of Malaga in the 'Pharmacy' section, but the basis for his work *Dictionary of Simple Remedies and Food*, an enormous pharmacological encyclopaedia, reflects his botanical skills, in this he studied three thousand different plants and their medical properties.

'and the leaves of the tree were for the healing and the restoration of the nations.'

The Bible, Revelation Chapter 22 verse 2

Chinese herbalists preparing herbal remedies

Opposite clockwise:
Venue from a [illegible] century Arabic botanical treatise, Dioscorides is handing his student a mandrake root regarded as a highly effective medicine (from a translation of Dioscorides's *De Materia Medica* copied in the early [illegible] century). Without early Arab Muslim scholars, we would have no knowledge of the Greek contributions. See also how Dioscorides has been clothed as a revered scholar by the author of this manuscript, Yusuf al-Mawsili from Baghdad, who shows respect to the Greek physician by also placing his feet so they are not in contact with the ground; botanical species from a treatise by Ibn al-Baytar of Malaga; the tapping of a balsam tree as shown in a [illegible] century Persian manuscript

One of the best herbal medicine books was produced by al-Ghafiqi, who died in 1165. This was called *The Book of Simple Drugs*. It was exceptionally accurate and was republished by Max Meyerhof in Egypt in 1932.

In the 10th century, Ibn Juljul wrote a commentary on Dioscorides's nine-hundred-year-old book *De Materia Medica* and translated it into Arabic, adding many new substances such as tamarind, camphor, sandalwood and cardamom. He also identified many new plants and their properties along with their medicinal values for treating various diseases.

A very simple but major breakthrough that Muslims made in herbal medicine was watching how the herb affected the patient. Now this seems quite an obvious thing to do, but they were the only ones using and relying on scientific methods of experimentation and observation at that time.

Elsewhere in medieval Europe, books on herbs were rare and known only amongst a small number of scholars, and until the end of the 15th century many Europeans were using the Arabic texts and Arabic versions of Greek texts translated into Latin. So between 1500 and 1600 there were about seventy-eight editions of Dioscorides, the Greek scholar.

The success of the European scholars was measured by what they borrowed from Muslim botanists and how they made Dioscorides more prominent, but things were not going well. The once great Salerno school was in decline because of a lack of ability in Latin, Greek and Arabic, and they did not fully understand the Greek texts as most of the time they were second-hand translations.

European herbalists were frustrated by ignorance, malpractice, faults in earlier bad Greek translations and also from not being able to correctly identify ingredients because they were described in local dialects. All this led Sir Thomas Elyot, a 16th-century English diplomat and scholar, to inform his readers that he derived no understanding from the ancients and that they gave 'no little profyte concernynge myne owne helthe'.

Fortunately, herbal medicine has done away with using mother's blood, which was sometimes added in certain medieval European recipes. Today, in the United Kingdom, one Briton in five uses complementary medicine and, according to a recent survey, one in ten uses herbalism or homeopathy. Around £130 million is spent on oils, potions and pills every year in Britain, and the complementary and alternative medicine industry is estimated to be worth £1.6 billion annually.

For Muslims today herbal medicine is regaining its importance as many herbal physicians have started to emerge, although in villages and rural areas herbal medicine has persisted through the centuries, as an integrated part of tradition.

Pharmacy

In nearly every high street and supermarket, a pharmacy or chemist can be found. Their hours vary but one will always be open and it's hard to imagine life without the ease of popping down to the local chemist to buy all those everyday life essentials.

But they aren't modern day concepts, as pharmacies were springing up in Baghdad, Iraq, eleven hundred years ago. At the beginning of the 9th century pharmacists were independent professionals running their own pharmacies, with the skills of compounding, storing and preserving drugs being handed down from father to son.

These family-run businesses operating in the markets were periodically (especially in the 12th and 13th centuries) inspected by a government appointed official, *al-Muhtasib*, and his aides. They checked the accuracy of weights and measures, as well as the purity of the drugs used, stopping the use of any bad and deteriorating drugs as well as getting rid of impostors and charlatans. So all pharmacists had to satisfy the rigorous inspection of the 'Health and Safety Executive', and were threatened with humiliating corporal punishment if they adulterated drugs.

Pharmacies were not only found in markets. Just like the hospitals and clinics of today, those of a thousand years ago had their own dispensaries and manufacturing units like primitive laboratories, producing various drugs like syrups, electuaries, ointments, and other pharmaceutical preparations.

There is no
ilment for
which God has
not created a
cure.'

Prophet Mohammad
(pbuh) narrated by
Sahih al Bukhari

ar right: Arabic version f Dioscorides *De Materia ledica* showing a pharmacy ith chemists preparing nedications.

So the practical side of pharmacology was well developed and supported by scholars like Sabur ibn Sahl in the 9th century, who was the first physician to describe a large variety of drugs and remedies for ailments; al-Razi, who promoted chemical compounds in medicine; Ibn Sina describing seven hundred preparations, their properties, actions and their indications; and al-Kindi determining and applying the correct drug dosage, which formed the basis of medical formulary.

In the 11th century, al-Biruni wrote one of the most valuable works in the field called *The Book of Pharmacology*, giving detailed knowledge of the properties of drugs, and outlining the role of pharmacy and the functions and duties of the pharmacist.

Other influential scholars included al-Zahrawi of Spain who pioneered the preparation of medicines by sublimation and distillation, which meant a whole range of new drugs could now be produced. He didn't stop there, because as he had already used catgut for internal stitching, he took this a step further and also administered drugs by storing them in catgut parcels which were ready for swallowing. So when you take a drug capsule today remember that its forerunner is over a thousand years old.

Al-Zahrawi's work *al-Tasrif* was translated into Latin as *Liber Servitoris* and told the reader how to prepare 'simples,' and from these, to compound complex drugs. He also gave methods of preparing substances like litharge or lead monoxide, white lead, lead sulphide (burnt lead), burnt copper, cadmia, marcasite, yellow arsenic and lime, and numerous vitriols and salts.

Abu al-Mansur Muwaffaq broke new ground when he wrote *The Foundations of the True Properties of Remedies* in the 10th century. This described arsenious oxide and he knew about silicic acid. One use of this today is in pills

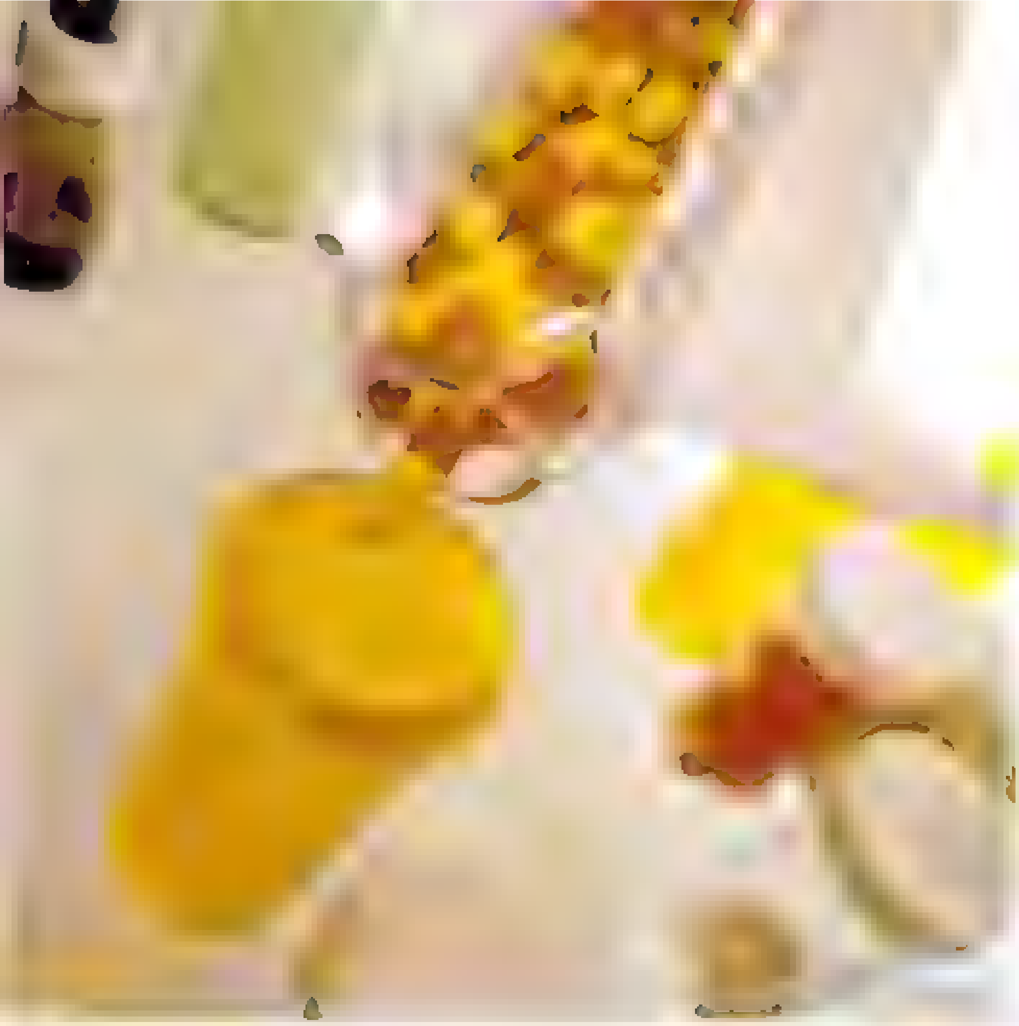
that help form a protective membrane in easily irritated stomachs. He made a clear distinction between sodium carbonate and potassium carbonate, and drew attention to the poisonous nature of copper compounds, especially copper vitriol, and also lead compounds. He also mentioned the distillation of seawater for drinking.

A primary aim of the pharmacists was that their work had to be expertly organized, making it of maximum practical value to the apothecary and medical practitioner. This meant that they listed drugs alphabetically in tables for easy referencing and quick usage, and medical encyclopaedias were available as full works or sections on medical specialities.

These early drug treatises passed into Europe with all this vital pharmaceutical information, influencing 13th-century European pharmacists like Johannes of St Amand and Pietro d'Abbano, a professor in Padua, Italy from 1306 to 1316. Works that took this European journey included books by Ibn al-Wafid of Spain who was published in Latin more than fifty times. His main work was called *The Book of Simple Drugs* and ran to five hundred pages, taking twenty-five years to compile. The Latin translation, *De medicamentis simplicibus*, is only a fragment of all his work.

Whilst translating Arabic texts, American historian Martin Levey, found information on compound drugs, pills, pastilles, powders, syrups, oils, lotions and toothpastes.

Persian pharmacy jar, 12th century. This earthenware jar was used by apothecaries to store dried herbs, minerals and other medicines. The glazed surface of pottery drug jars, such as this one, could be easily cleaned.



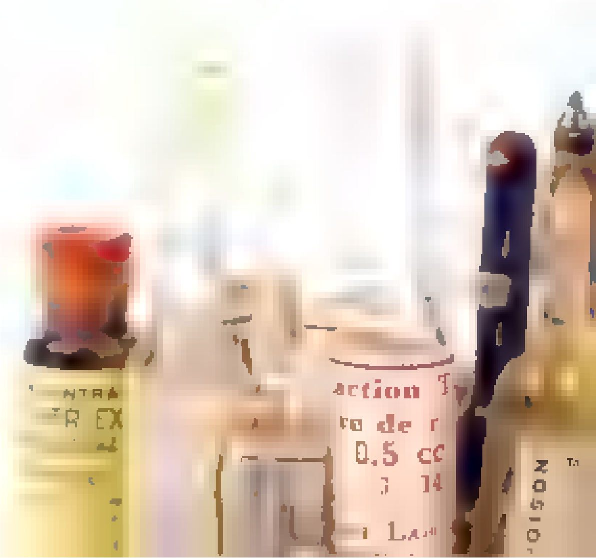
A thousand years ago, al-Zahrawi administered mixed powder drugs by storing them in catgut parcels which were ready for swallowing, a forerunner for today's drug capsule

As well as investigating the action of drugs, sleep and bathing, Ibn al-Wafid also wrote on farming, because agriculture, plant cultivation, botany, chemistry and medicine were closely linked. The 13th-century Malaga Muslim Ibn al-Baytar was a leading botanist as well as the author of the largest pharmacological encyclopaedia that has survived to our time. *Dictionary of Simple Remedies and Food* is an inclusive work on simple drugs and describes over three thousand botanical simples listed in alphabetical order. He took information from over one hundred and fifty authors and interweaved this with his own observations. A Latin version of the book was published in 1758, and its complete translation appeared in 1842.

European pharmacists were truly inspired by these works, so *Compendium aromatariorum*, written by well known 15th century physician Saladin of Ascolo, was divided into seven parts. It follows, exactly, the earlier Muslim categorization of subjects, including examination of the pharmacist, the qualities desired for the pharmacist, substitute drugs, and care of simple and compound drugs.

A Florence physician, Ludovico dal Pozzo Toscanelli, worked at the Florentine College of Physicians which produced a 17th century edition of the *London Dispensatory*. This listed botanicals, minerals, simple and compound drugs for external and internal uses, oils, pills and cataplasms, all showing a Muslim mark.

Muslim pharmacy was recently revived by an American historian, Martin Levey. Before he died in 1977 he had translated Arabic texts and unearthed huge lists of therapeutic treatments, books on poisons, preparations of the drugs and descriptions of their use, and substitute drugs (in case one drug for whatever reason was not available, a substitute could be provided). He found information on compound drugs, pills, pastilles, powders, syrups, oils, lotions and toothpastes. All this information is another reminder that those of a thousand years ago were not suffering horribly, but benefiting from sophisticated medicines and research.



Right: Arabic manuscript with pharmacological tables ascribed to 13th century Ibn al-Baytar showing descriptions of symptoms, locating the ailment and applications of medicine, and what dosage should be used

[illegible]	منفعته في جميع البدن	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ينفع الرياح وعلل النفخ ويفتح سدد الكبد والطحال والكلى ويدر البول والحيض ويكسر البطن ويزيد في الباه	ينفع من حميات بلغمية النائبة من حميات المزمنة وينفع ضرر السموم والهوام ويدر العرق وبخاره ينفع من الورم الحادث في الاطراف والتهييج	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ما
يسكن الاوجاع الباطنة في جوف المعدة ويدر البول والحيض ويفتت الحصاة ويقوي الكبد ويفتح سددها وينفع من حموضة المعدة والورم الصلب فيه ويشهي الطعام [illegible]	ينفع من الاورام الباطنة المكية شربا وضمادا وضماد ينفع من الحكة والجرب والبرص ويذهب الاعيا	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.ما
يسهل الصفرا وينفع المعدة الباردة ويقويها وينفع اليرقان ويفتح سدد الكبد وينفع من الاوجاع الباطنة ويدر البول والحيض ويقتل الديدان وينفع من البواسير	ينفع من حميات المزمنة ويحسن اللون وعلا اعلابا ضمادا ويزيل الاثار البنفسجية وينفع من السموم ولدغ العقارب ويطرد الهوام بخورا	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ح
يسهل الخلط السوداوي والبلغم ويفتح السدد ويخرج الديدان والحيات ويقوي الاعضا الباطنة	ينفع من وجع المفاصل ومن جميع السموم واللدوغ	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ط
يسهل الخلط السوداوي ويخرج الدود والحيات وحب القرع وعلل النفخ وينفع الباه وينفع [illegible]	ينفع من حميات الربع والجرب السوداوي والبهق الاسود والبرص شربا	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	كا

European Medicine

MUSLIM MEDICS OF A THOUSAND YEARS AGO would be happy to learn that a few decades, sometimes centuries, after their deaths their works were being translated into Latin, making them accessible to the whole of Europe. Even more people would benefit from their studies and as they wanted to better society, and in medical terms this meant relieving human suffering, this was an excellent development, not only for them, but also for their Christian counterparts.

Tunisia was a hotbed of medical knowledge because of a pioneering hospital called al-Qayrawan that was built in 830 CE. You can read about this in the 'Hospital Development' section. As well as being a practising hospital, al-Qayrawan had medical scholars producing enormous medical tomes of knowledge and these were taken to Europe by people like Constantine the African.

In the 11th century, this Tunisian (Muslim and later Christian) scholar translated medical encyclopaedias so they were available to Latin speaking Europeans. This revolutionized the whole of medical study in Europe, while also creating a generation of prominent medical teachers. Constantine's best known translation is of *The Royal Book* by 10th century physician Ali ibn Abbas al-Majusi, known in Latin as the *Pantegni*. It was printed in Lyons (France) in 1515 and in Basel (Switzerland) in 1536. This is amongst the best of classical works on Muslim medicine.

The 9th century Great Mosque of al-Qayrawan in Tunisia was a complex consisting of a hospital and mosque

... Greek science, which we think of as the source of everything, was already reformed, already critiqued, and alternative science was built in the Islamic world hence a Renaissance person would have thought about Arabic science being the latest state of the art

Dr George Saliba, Arabic and Islamic Science, Columbia University speaking with Rageh Omar on the BBC's An Islamic History of Europe

Constantine must have had a head bursting with information because he also translated several works on subjects like diets, the stomach, melancholy, forgetfulness, sexual intercourse and most importantly *The Guide for the Traveller Going to Distant Countries*. This was a very accessible introduction to pathology, the study of diseases.

The Guide for the Traveller Going to Distant Countries or *Traveller's Provision* was a medieval bestseller written by the physician Ibn al-Jazzar who practised and studied at al-Qayrawan hospital. There he died in 955, over eighty years old, leaving 24,000 dinars and twenty-five quintars (one quintar is forty-five kilograms) of books on medicine and other subjects. His legacy also included a treatise on women's diseases and their treatment. According to this, menstruation played a central role in maintaining women's health as well as in causing women's diseases. Such writings earned him immense fame and made him very influential in medieval western Europe.

Constantine translated *Traveller's Provision* into Latin as *Viaticum peregrinantis* and Synesios translated it into Greek and Hebrew as *Zedat ha-derachim*, which propelled it to international bestseller and most read status.

Just as travellers today seek advice on how to handle all kinds of ailments on the road, travellers in medieval times also needed a reference book to see them through the bad times. Not only for travellers, *Traveller's Provision* was a systematic and comprehensive medical work accepted into the so-called *Articella* or *Ars medicinae*, a compendium of medical textbooks widely used in medical schools and universities at Salerno, Montpellier, Bologna, Paris and Oxford. It contained remarkable descriptions of smallpox and measles.

The cover of a 16th century illustrated work showing Constantine the African lecturing at the school of Salerno. Constantine was an 11th century Tunisian Christian (originally Muslim) who translated medical encyclopaedias


DE CONSERVANDA BONA VALETVDINE, Liber Scholæ Salernitanæ.

DE ANIMI PATHEMATIS, ET remedijs quibusdam generalibus.

CAPVT I.

1 ANglorum Regi scribit schola tota Salerni.

2 Si vis incolumem, si vis te reddere sanum,

3 Curas tolle graueis, irasci crede profanum.

'The European medical system is Arabian not only in origin but also in its structure. The Arabs are the intellectual forebears of the Europeans.'

Dr Donald Campbell, 20th-century historian of Arabian Medicine

Cover of *Kitab al-Maa* or *The Book of Water*, written by Ibn al-Thahabi and recently published in Oman.

Constantine was not alone, as his translation work was continued by his pupil, a Muslim called Joannes Afflacius, also known as Joannes Saracenus or John the Saracen, who died in 1103. He was also a physician at the Salerno hospital, and authored treatises on urology and fevers.

The translated Arabic works soon became popular in all centres of learning, including Salerno, a major centre of learning in Europe with its medical school.

Other translated medical works that had a major impact on Europe included those by Ibn Sina, known as the 'Prince of Physicians' in the West. His 11th century *Canon* was another enormous medical encyclopaedia which remained the supreme authority in the world, dominating the medical sciences for around six centuries, describing over seven hundred and sixty drugs. You can read more about him and his work in the 'Bone Fractures' section.

His scientific, philosophical and theological views left their mark upon many important figures such as Albertus Magnus, St Thomas, Duns Scotus and Roger Bacon.

The first known alphabetical classification of medical terms, listing the names of illnesses, medicines, physiological processes or treatments was called *Kitab al-Maa* or *the Book of Water*. Written by al-Azdi, also known as Ibn al-Thahabi, it was called *Kitab al-Maa* because the word *al-Maa*, the water, appears as the first entry. The author, who died in 1033, in Valencia, Muslim Spain, left this nine hundred page manuscript for the benefit of his contemporaries and future generations.

Al-Razi's twenty-volume 'Comprehensive Book' covered every branch of medicine. Translated into Latin as *Liber Continens*, it was probably the most highly respected and frequently used medical textbook in the Western world for several centuries. It was one of the nine books that composed the whole library of the medical faculty at the University of Paris in 1395.

Then there was the work of al-Zahrawi, an outstanding physician in Cordoba, southern Spain around the year 1000. His weighty tome of medical knowledge was known as *al-Tasrif*. Its complete name was *Al-Tasrif li-man 'ajaza 'an al-taalif*. In English it was known as *The Arrangement of Medicine*, although the literal translation was 'The book of enabling him to manage who cannot cope with the compilations', which is very explanatory as to its contents. So this was a very practical guide, remarkable for its eyewitness, personal accounts.

The whole work made up a compendium of thirty volumes compiled from medical data that he accumulated in a full medical career and practice. He apparently travelled very little but had wide experience in treating accident victims.

What was outstanding about the book was that it established the rules of practical medicine by emphasizing the dos and don'ts in almost every medical situation encountered. Then it went on to give the solutions and treatments al-Zahrawi had discovered and finely tuned during this long experience.

Al-Tasrif remained the single best medieval source on surgical instruments until modern times. The volume 'On Surgery' is extraordinary due to the illustrations of over two hundred surgical instruments, which you can read more about in the 'Instruments of Perfection' section.

His surgical techniques were also revolutionary, and the surgical part of *al-Tasrif* was translated into Latin by Gerard of Cremona, with various editions being published at Venice in 1497, at Basel in 1541 and Oxford in 1778. Now all his knowledge and painstaking operations were accessible to Europeans and *al-Tasrif* became a reference book and manual of surgery for most European medical schools, like Salerno and Montpellier, playing a central part in the medical curriculum for centuries.

Practitioners also used it and L. Leclerc, a 19th century French physician and medical historian, summarized the impact of *al-Tasrif* by writing 'The Translation (of *al-Tasrif*) played a significant role in the development of medieval surgery in Europe.'

Al-Tasrif can be found today in many libraries including the Library of Congress in the United States of America.

Lastly, we stop by the work of Ibn Nafis, a Syrian physician who died in 1288. He has left us *The Complete Book on Medicine*, which was compiled in eighty volumes. Manuscripts of portions of this huge work are now available in collections in Damascus, Aleppo, Baghdad, and Oxford, as well as Palo Alto in California which has a large fragment in Ibn Nafis's own handwriting.

Frederick II, Holy Roman Emperor and King of Sicily, a very modern ruler for his time (the 13th century), was interested in the work of the Muslims. He was a patron of science and learning and sent the medieval scholar Michael Scott to Cordoba to obtain works by 11th century physician Ibn Sina, whom you can read more about in 'Ibn Sina's Bone Fractures'. Copies were then distributed to existing schools.

A lot of medical knowledge, techniques, drugs and remedies were received through translation but some came through direct contact with Muslim physicians as they treated crusaders. They were renowned for their medical superiority, and even Richard the Lionheart was treated by the personal physician of Saladin.

The hard work and tenacity of Muslim medics was quite astounding. The pages they covered spread standards of hygiene and preventative medicine and they were responsible for the improvement of the general health of the masses in the so-called 'dark' ages.

First published in 1858, *Gray's Anatomy* is a leading medical encyclopaedia today following on the tradition begun by Muslims whose treatises gained equal popularity at universities.

05 TOWN

'The arch never sleeps.'

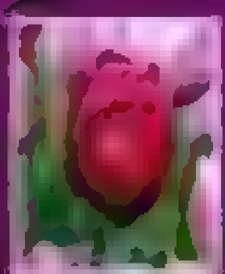
Arabic Proverb

Life in cities like 9th and 10th-century Cordoba in Spain and Baghdad in Iraq was a pleasurable experience. This was high civilization with free education and health care plus public amenities like baths, bookshops and libraries lining the paved streets, lit at night. Rubbish was collected on a regular basis by donkey carts and some sewage systems were underground.

Neighbourhoods were peaceful, with houses off main thoroughfares, connected by narrow winding and shade giving streets, all within earshot of the local mosque. All business and trade was kept to the main streets and public squares. Gardens, both public and private, were an imitation of Paradise with attention and care to details.

Huge water-raising machines could be seen pumping water from rivers into the fields and to the cities. The fountains of the Alhambra Palace in Granada, Spain still use the six-hundred-and-fifty-year-old water systems devised by Muslim engineers.

Advances in architecture, particularly in arch and vault buildings, saw huge mosques and crevice spanning bridges. Domes and minarets dominated the skyline and were so impressive that returning crusaders took these ideas, and sometimes the Muslim architects themselves, with them to build on European soil.



Town Planning

JUST AS TRADITIONAL EUROPEAN TOWNS have certain features like market squares, churches and parks, Muslim towns were also designed according to the local populations' needs, based on four main criteria: weather and landscape, religious and cultural beliefs, *Sharia* Muslim law, and social and ethnic groupings.

Many of these cities were in fiercely hot climes, so a lot of shade was needed. To provide this, towns were planned with narrow covered streets, inner courtyards, terraces and gardens.

Religion was vital to cultural life, so the mosque, like a church, had a central position. Around this mosque grew narrow, winding, quiet streets that led away from the public places into private life and cul-de-sacs. Any economic activity, buying or selling was strictly in public areas and main streets, leaving the residential and private houses in peace. Social and legal issues were handled by the religious elite, who lived in central places close to the main mosque, the main public institution.

The city had to stick to the rules of *Sharia* (Islamic Law) in terms of physical and social relations between public and private realms, and between neighbours and social groups. So the law, for example, set the height of the wall above the height of a camel rider, so a passer-by couldn't see into a property.

How and where people lived was based on families and groups of people from the same families and tribes with similar ethic origins and cultural views. Separate quarters, called *Ahyaa*, developed for each group, so there were quarters for Arabs, Moors, Jews and other groups such as Andalusians, Turks, and Berbers in cities of the Maghreb, North Africa. Some North African cities were divided into quarters for Muslims, Christians and Jews and this was often voluntary and not exclusive. Within these quarters they had kinship solidarity, defence, social order and similar religious practices.

Below left to right: 16th-century manuscript showing the town plan of Diyarbakir in South East Turkey; aerial view of an Andalusian village, Zuheros, Cordoba, Spain

A quiet and narrow Cordoba street, which is a typical feature of old Muslim town planning

These quarters did not prevent the society being socially cohesive, as the general trend was to follow the teachings and instructions of Prophet Mohammad (pbuh), who had said that 'There is no difference between an Arab and a non-Arab except by the extent of their righteousness' (narrated by Ahmad b Hanbal, *Musnad*).

These extended family structures, the need for privacy, sex separation and strong community interaction could all be catered for by the courtyard houses, and the neighbourhoods they created then took on the feeling of a semi-private space. This was because the houses were inward-looking with lattice work on windows, private doors and passageways.

There wasn't any real centrally administered city planning. Administrative centres like schools, hospitals and mosques were supported by private religious endowments called *waqfs*, and property laws were left to customary law on the local level.

So the four criteria of town development, weather and landscape, religious and cultural beliefs, *Sharia* 'Muslim' law, and social and ethnic groupings, meant that urban areas grew in zones. The main mosque was at the centre, with a *souk* or market next, then a citadel near an outer defensive wall surrounding residential quarters, all joined by an intricate street network to the outer wall. Then there was life outside the wall.

The souk was split into areas for spices, gold, fish, perfume and other goods, with items such as candles and incense being sold close to the mosque. There would also be booksellers and binders nearby too. In the *souk* and near the mosque was a central area for social gatherings, administration, trade, arts and crafts, *hammam* baths and hotels.

The citadel, like a western castle, was the palace of the governor, surrounded by its own walls. It was a district on its own, with its own mosque, guards, offices and residence. It was usually in a high part of the town near the outer wall.

Neighbourhoods clustered around mosques and couldn't be further than the muezzin's call to prayer. Even though the residential quarters seemed quiet, they were hives of activity and had a quality of life based on closeness from personal ties, common interests and shared moral unity. Being densely packed, each had its own mosque, school, bakery and shops. They even had their own gates, which were usually closed at night after last prayers and opened every morning at early prayer time.

The al Azhar Mosque Cairo, Egypt founded in 972, and pictured here in 1831. The mosque played a central role in the everyday life of Muslims. It was located at the heart of the city, with homes and businesses branching out from it in different directions.

All this was surrounded by a well defended wall with a number of gates, and outside the wall were Muslim and Jewish cemeteries. A weekly market was also just outside the main gate with most animal *souks*, as were more private gardens and fields.

The most elaborate city of its day, the New York of the 9th century, was Cordoba. The '... physical sides [of Cordoba] reveal an ingenious and inventive Muslim culture. They were clearly driven to improve on the past, to modernize the city and make it a better place to live in, not just for the rulers but for everyone ... There were dozens of libraries, free schools, and houses had running water and what's more, the streets were paved and they were lit, the kind of amenities London and Paris wouldn't have for seven hundred years,' said reporter Rageh Omar presenting the BBC's *An Islamic History of Europe*.

The streetlights were oil burners and lanterns, lit at sunset, and each city district employed people to maintain them. Litter was also collected on the back of donkeys, who took it outside the city walls to special dumps. The streets were drained by a system of great sewers and cleaned daily, and the sewage was in a network of canals which mostly ran immediately below the ground. A few were open and located in the middle of the street for quick cleaning and draining.

During this time Paris was known as 'The Muddy' because pedestrians were blocked by heaps of steaming offal and garbage, with pigs scavenging through courtyards and streets.

In southern Spain today, cities like Seville and Cordoba still have mues of winding streets and fabulous houses that, from the outside, seem plain, but if you're lucky enough to be invited in, a spacious splendour will greet you, as tiled and courtyard gardens boast fine taste and cool shade, perfect ointments for summers that can reach forty degrees centigrade.

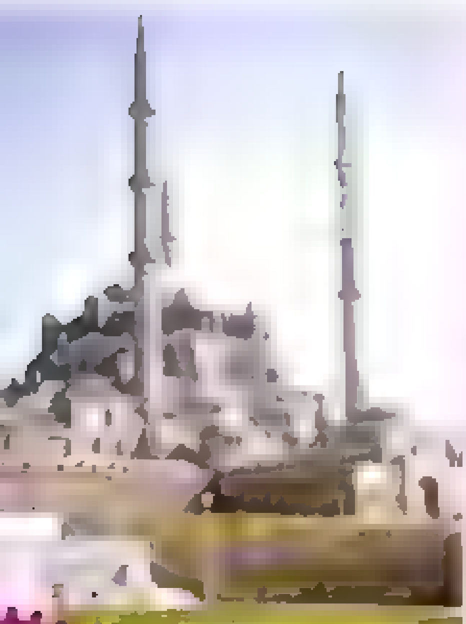
A 16th-century manuscript from the *Hünername* of Seyyid Lokman, depicting the daily activities of people and showing the first courtyard (Birinci Avlu) between the gates of Bab-ı Hümayun and Babüsselam in the Topkapı Palace, Istanbul

Architecture

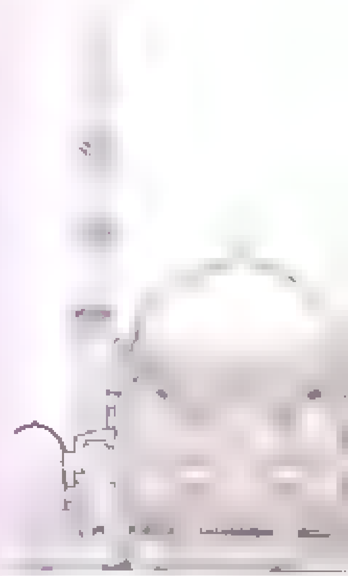
Many European buildings today have distinct characteristics and features like domes and rose windows on cathedrals, the arches of train stations and vaults in churches. It may surprise you to learn that many of these were developed and perfected in architectural terms by Muslims, and flowed into Europe a thousand years ago via southern Spain and Sicily. Building designs and ideas were also taken home by scholars, crusaders and pilgrims visiting Jerusalem as they travelled overland through Muslim countries and cities like Cordoba, Cairo and Damascus.

For Muslims, architecture had to get across a number of ideas, like Allah's or God's infinite power, which was shown in repeated geometric patterns and arabesque designs. Human and animal forms were rare in decorations because Allah's work was matchless. So instead, highly stylized foliage and flower motifs were used. Calligraphy then added a final touch of beauty to the building by quoting from the Quran, while large domes, towers and courtyards gave a feeling of space and majestic power.

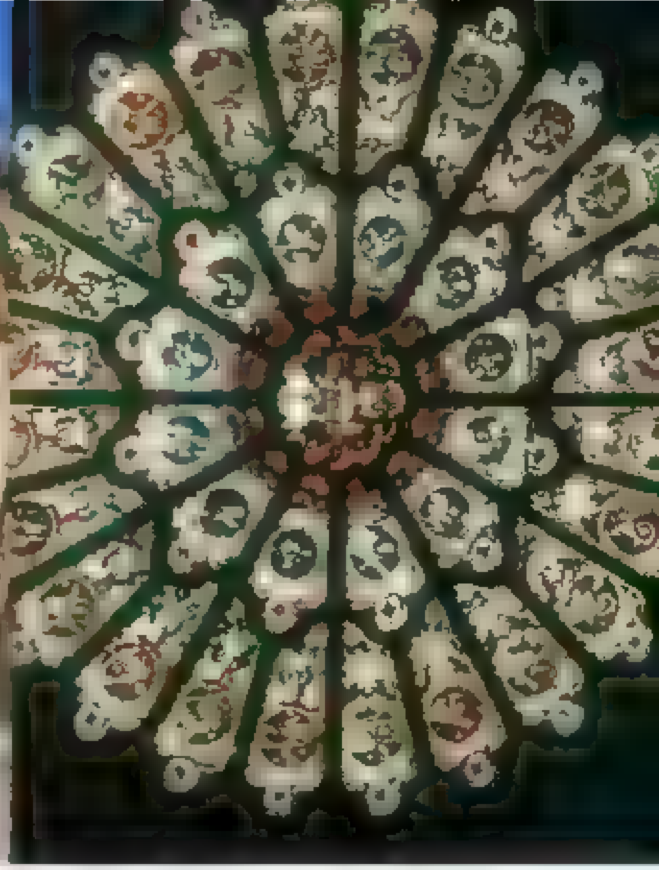
The decoration of these buildings really concentrated on visual aesthetics, because although Islam opposes unnecessary spending, it doesn't oppose having a comfortable life or enjoying it, as long as people live within the boundary of God's law and guidance. This all means Muslims don't have to live miserably. The Muslim wisdom 'Strive for your earthly life as you live forever and strive for your hereafter as you will die tomorrow' really sums up the Muslim attitude to architecture too; if you're going to make it, make it modestly and beautifully.



The Selimiye Mosque in Edirne possesses the highest, earthquake-defying minarets in the whole of Turkey. It is the work of master architect Sinan, who was the architect for the Ottoman Empire. He designed and built a staggering 477 buildings during his long career in the service of three sultans in Turkey during the 15th century, acknowledging the importance of harmony between architecture and landscape, a concept which did not surface in Europe until the 16th century. His Turkish designs revolutionized the dome, allowing for for greater height and space, an outstanding advance in civil engineering which later became his trademark.



The circular window at Khirbat al-Mafjar, Jordan, from 740-[illegible] thought to be the origin of the rose window in Durham cathedral.



The rose window in Durham cathedral.

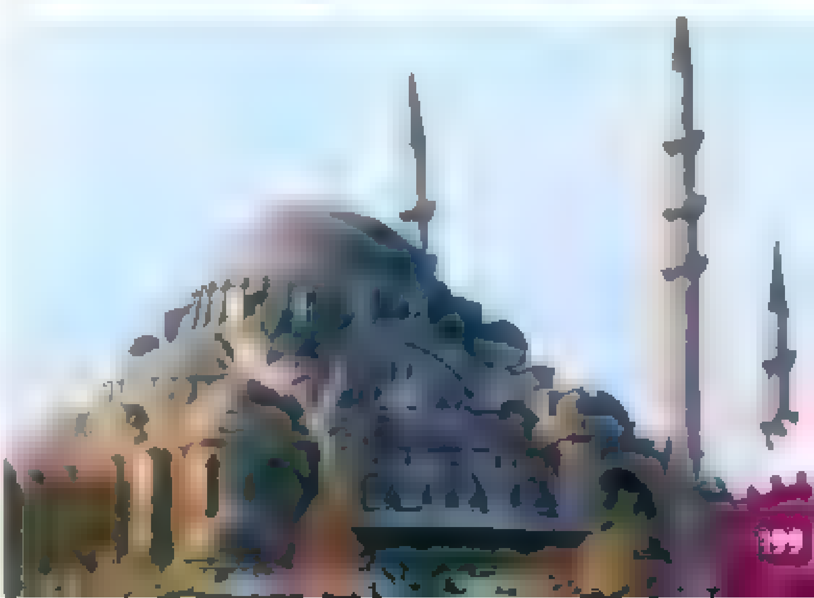
Rose windows are a good example of this. Looking at the façades of most European cathedrals and churches you can't help noticing their imposing beauty and how they decorate the curtain walls above the main entrance. You'll be surprised to learn that historians related the origin of these huge circular windows to Islam, and the six-lobed rosettes and octagon window on the outer wall of the Umayyad Palace of Khirbat al-Mafjar. This was built in Jordan between 740 and 750.

The crusaders saw this and introduced it into their European churches, first in Romanesque architecture (11th to 12th centuries), in places like Durham cathedral, and later in Gothic architecture. The rose window had a function of letting both light and sun in, while supposedly symbolizing the eye of the Lord. Others, though, claim the idea is from the Roman oculus, a circular window in the dome of the Pantheon in Rome, but this was more like a circular opening pierced in the roof.

This example is just a taster of what you will discover in the following sections about the varied world of Muslim architecture and how it influenced global building styles over the centuries.

Muslim architecture often has environmentally friendly features. To reduce smoke pollution from the thousands of candles and oil lamps, Sinan designed the interior space of the Suleymaniye Mosque in Istanbul so that the soot was channelled by air circulation into a filter room before being discharged into the city. The collected soot was conveyed into a water fountain, where it was mixed and stirred to produce high quality ink that was used in calligraphy. This ink also repelled bugs and bookworms, which prolonged the life of the manuscripts.

The Suleymaniye Mosque [illegible] designed by a great Sinan, crowns one of Istanbul's seven hills. The building [illegible] a madrasa, hospital, dining hall, caravanserai, hammam, hospices and shops. It was also an environmentally friendly design of stopping candle soot from polluting the atmosphere.



Arches

ARCHES ARE ESSENTIAL IN ARCHITECTURE because they span large spaces while also bearing huge loads. Being strong and flexible, they have been made bigger and wider, and today we can see them in buildings from shopping centres to bridges. They are so common nowadays that it's easy to forget how advanced arches were for their time a thousand years ago.

In the simplest arch the thrust comes from the weight of the masonry on top of the arch, and sideways from the cumulative wedge action of the voussoirs or the arch bricks. This gives the arch 'elasticity' and it can be compared to a hanging load chain, 'the arch stands as the load chain hangs.' This silent dynamism of the arch was known in the Muslim world through the saying 'the arch never sleeps.'

Muslims were the masters of the arch, and they loved this motif as much as they loved palm trees, imitating the curve of its graceful branches in their constructions. The spherical nature of the universe was an inspiration for its development too.

Knowledge of geometry and the laws of statics meant that various types of arches were dreamt up. What Muslims did structurally was to reduce the thrust of the arch to a few points, the top and sides. These could then be easily reinforced, leaving other areas free from support, so lighter walls and vaults could be built, saving materials in building.

The Egyptians and the Greeks used lintels, while the Romans, and later the Byzantines, built semi-circular arches. The Romans used an odd number of arch bricks with a capstone or keystone being the topmost stone in the arch. This shape was simple to build but not very strong. The sides would bulge outwards, so they had to be supported by masonry pushing them back in.

All these predecessors of the arch were inherited by Muslims, who had grand plans for their mosques and palaces. For these, they needed strong arches spanning great distances, which looked good as well. So they developed new forms like the horseshoe, multi-foil, pointed and ogee arch, all crucial for architectural advancement.

Left to right: Part of the west elevation of the Great mosque at Cordoba after the fourth enlargement (961–976) showing all the following in brickwork: a flat arch (lintel) immediately above the doorway, a semi-circular horseshoe relieving arch above it, blind cross-arches above the panel to the doorway, and five-lobed (or cinqfoil) arch above the window; the clock tower of Big Ben at the Palace of Westminster, London (1859) showing the adoption of a series of arches of the five-lobed form.

Horseshoe arch at the Great Mosque of Cordoba, Spain

The Horseshoe Arch

The horseshoe arch was based on the semi circular arch, but it was extended slightly beyond the semi circle. It wasn't so strong but looked impressive, and was the first Muslim arch adaptation, used in the Umayyad Great Mosque of Damascus, which was built between 706 and 715 CE. In Islam, the horseshoe is a symbol of sainthood and holiness, and not luck like other cultures. Structurally, the horseshoe arch gave more height than the classical semi-circular arch.

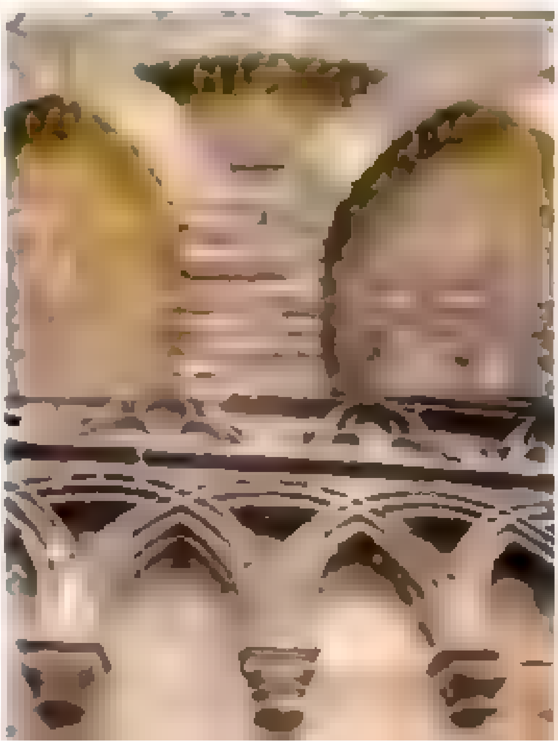
The first time it appeared on European soil was in the Great Mosque of Cordoba, whose building started in 756 and lasted forty years. The arch then travelled north with the Mozarabs, the Christian Spanish living in Andalusia. They were artists, scholars, builders and architects, moving between the southern and northern Christian parts of Spain.

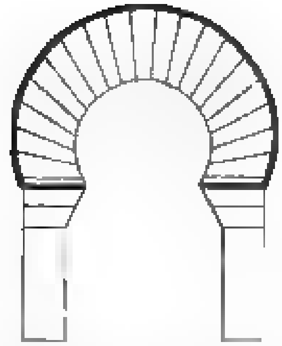
These arch designs could be found in great illustrated manuscripts, the architect's master plans, drawn by the Mozarabs. One was called *Beatus of Lebana* and its author, named Magius, worked at the monastery of St Miguel de Esacalda, near Leon. This was a large religious building in the Moorish style with horseshoe arches, and was built by monks arriving from Cordoba in 913 CE.

The horseshoe arch is known in Britain as the Moorish arch. It was popular in Victorian times, and used in large buildings like the railway station entrances in Liverpool and Manchester. These were designed by John Foster in 1830, and the arches of these two buildings are like those in the Gate of Cairo. Today, you can see the horseshoe arch in the front gate of Cheetham Hill Synogogue in Manchester (1870).

Intersecting Arches

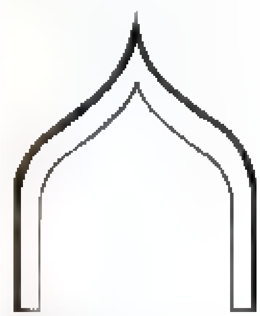
Muslims were so confident of their mastery of the arch that they carried out some spectacular experiments with forms and techniques of its construction. One of these was the introduction of intersecting arches, which provided an additional structural bonus. It meant they could build bigger and higher, and add a second arch arcade on top of a first, lower level. This can be seen best in the Great Mosque of Cordoba.





Horseshoe Arch

Pointed Arch



Left top to bottom: Intersecting arches at Bab Mardum Mosque (now called Church of Cristo de la Luz) built between 998 and 1000 CE in Toledo, Spain; decorative intersecting arches at Bolton Abbey, UK built in the 12th century

Left to right: In Europe the pointed arch was first used in the porch of the Abbey of Monte Cassino, in the reconstruction of 1071 CE and then passed north into the Church of Cluny, during the reconstruction of 1088 CE. The arch is now found in buildings like Bolton Abbey UK, built in the 12th century. The pointed arch came to Europe from the Ibn Tulun Mosque of Cairo (below), built in 876 CE via Sicily with Amalfitan merchants.

The Pointed Arch

The main advantage of the pointed arch was that it concentrated the thrust of the vault on a narrow vertical area that could be supported by a flying buttress, a major feature of European Gothic architecture. This meant that architects could lighten the walls and buttresses which had previously been massive to support semi-circular arches. Other advantages included a reduction of the lateral thrust on the foundations, and allowing for level crowns in the arches of the vault, making it suitable for any ground plan.

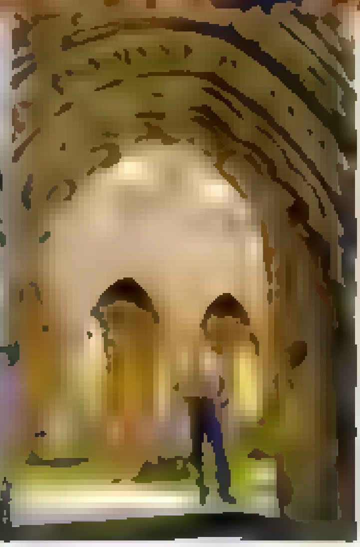
Many people think that the pointed arch, on which Gothic architecture is based, was an invention of European architects trying to overcome problems in Romanesque vaulting, but it came to Europe from Cairo via Sicily with Amalfitan merchants. They were trading with Egypt in 1000, and it was here that the beautiful Ibn Tulun mosque of Cairo displayed its mighty pointed arches. In Europe, it was first used in the porch of the Abbey of Monte Cassino in 1071, which Amalfitan merchants generously financed.

At this time in the late 11th century, Monte Cassino became the retiring place for the Tunisian Christian scholar, Constantine the African, whom you can read about in the "Translating Knowledge" section in the School chapter. A physician, translator and a distinguished scholar in mathematics, science and theology, he also had a great deal of experience of Muslim building techniques, gained from the Muslim Fatimid of North Africa. Constantine would have undoubtedly given his opinion during the building process in Monte Cassino.

The pointed arch was then passed north when St Hugh, the Abbot of Cluny in southern France, visited Monte Cassino in 1083. Five years later work on the third Church of Cluny started and it eventually had 150 pointed arches in its aisles. This was destroyed in 1810. But the journey of the arch did not stop there, as the next person in its travel chain was Abbot Suger who visited Cluny between 1135 and 1144. He and his engineers went on to build St Denis, the first Gothic building.

The adoption of pointed arches and other Muslim motifs in Cluny and Monte Cassino, the two most influential churches in Europe, encouraged the rest of Christian Europe to take them on. Like any new fashion it rapidly spread across much of France, especially in the south, then to Germany in the mid 12 century, and eventually to the rest of Europe. In Britain there were many buildings which had these arches, almost all of them religious buildings.



Far left: Indo-Islamic version of four pointed arch at the tomb of Humayun outside Delhi, built in the 16 century

Above: Inside the Great Mosque of Cordoba with super imposed arches on the left and multi-foil arches to the right, these were built in succession between the 8 and 10th century

Left to right: Multi-foil arch at Tintern Abbey, UK, built in the 12th century; typical ogee arch known as a Gothic arch in Europe

The Multi-foil Arch

It was in Samarra in Iraq that the first multi-foil arch was designed before passing into the rest of the Muslim lands including Spain and Sicily, and then to Europe. Its first appearance was in the windows of al-Mutawakkil Mosque, built between 848 and 849 in Samarra. These windows were on the enclosure and spanned by cinqfoil arches.

The multi-foil arch reached North Africa and Andalusia, where it became very popular, decorating most Moorish buildings, especially Cordoba Mosque. From the 10th century, Europeans fell in love with it and adopted it in their buildings, plans, and arts. Its most popular use was in the trefoil form which suited the concept of Trinity in Christianity. Like many of these arches, those seen in the Cordoba mosque were the main inspiration.

Ogee Arch

After the semi-circular arch entered Europe, one of the most important arches was the ogee arch, otherwise known as the Gothic arch in Europe. This is an elegant arch, a stylized development of the pointed arch. The arch curve is constructed in the form of two 'S' shapes facing each other and was used mostly for decoration, sometimes with a stone knot at the top. The arch was developed in Muslim India, and later reached Europe in the 14th century, becoming particularly popular in late Gothic, 16th-century architecture in Venice, England and France.

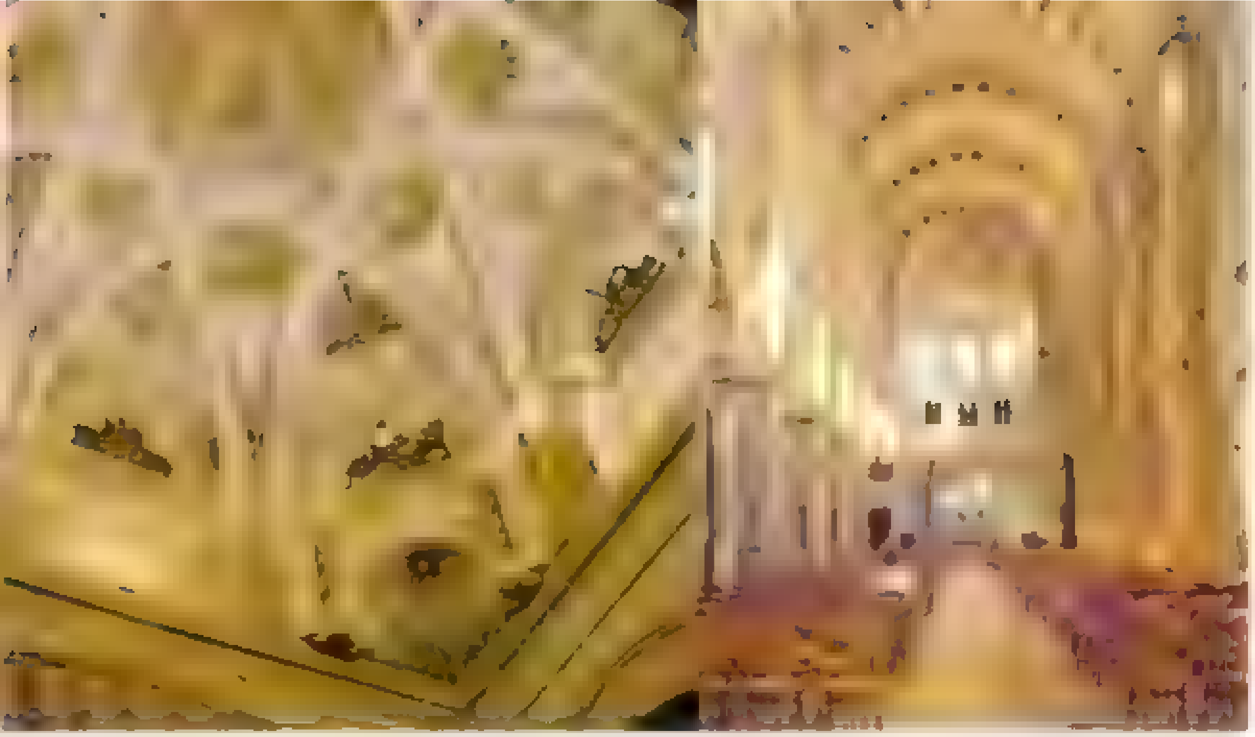
You can see it everywhere in England, because almost all churches and cathedrals have a full ogee arch, or use it in the form of an ogee moulding. They are both used in decorative screens, entrances, and later Gothic styles.

Vaults

AN ARCHITECTURAL VAULT is a stone arch that makes a ceiling or canopy, making it possible to have a roof over a large space made of bricks, stone blocks or rubble. Until metal girders and trusses were introduced in the 19th century, the only alternative to stone vaults were long wooden rafters or stone lintels. These were much simpler materials to use but weren't as sophisticated and were more expensive, while building was also limited by the length of the wood.

Vaults, like arches, were used by the Romans, but Muslims refined them so they could build bigger and higher. They made vaults that were as strong, but finer, with thinner curtain walls, so more light was let in. Until the 11th century Europe used thick Roman vaults, which needed robust (as thick as two metres) and short walls to carry them, but when they saw the Muslim vaults of Cordoba, they imitated their design and techniques. So, these became typical of the Romanesque period (10th to 12 centuries) in Europe and they were first seen in great cathedrals, like Durham in England

Left: A catacomb of an old castle



Left to right: Rib vaulting in the maqsura dome of the Great Mosque of Cordoba, added in the 10^{th} century; ribbed, tunnel vaults at 12^{th} century Sainte Madeleine in Vezelay, France, resembling those of Susa, built in 821–822

Rib Vaulting

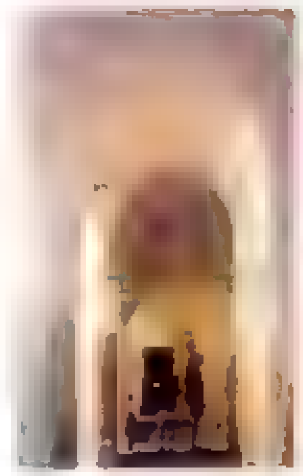
The Great Mosque of Cordoba, called the Mesquita, was the springboard for much of European architecture. Its vast hall of polychrome, horseshoe and intersecting arches, ribbed vaults and domes all made their way north, and it is worth noting that ribbed vaults do not appear in churches that existed then, such as those in the Leon region, because they were built before the Great Mosque of Cordoba.

A ribbed vault was a ceiling or canopy of stone that was strengthened by single semi-circular arches added beneath the vault to provide extra support. These added arches looked like ribs, and they supported the crown. This meant a large amount of the thrust of the vault was concentrated on these ribs, relieving the pressure on the walls, enabling the builder to make them thinner and higher.

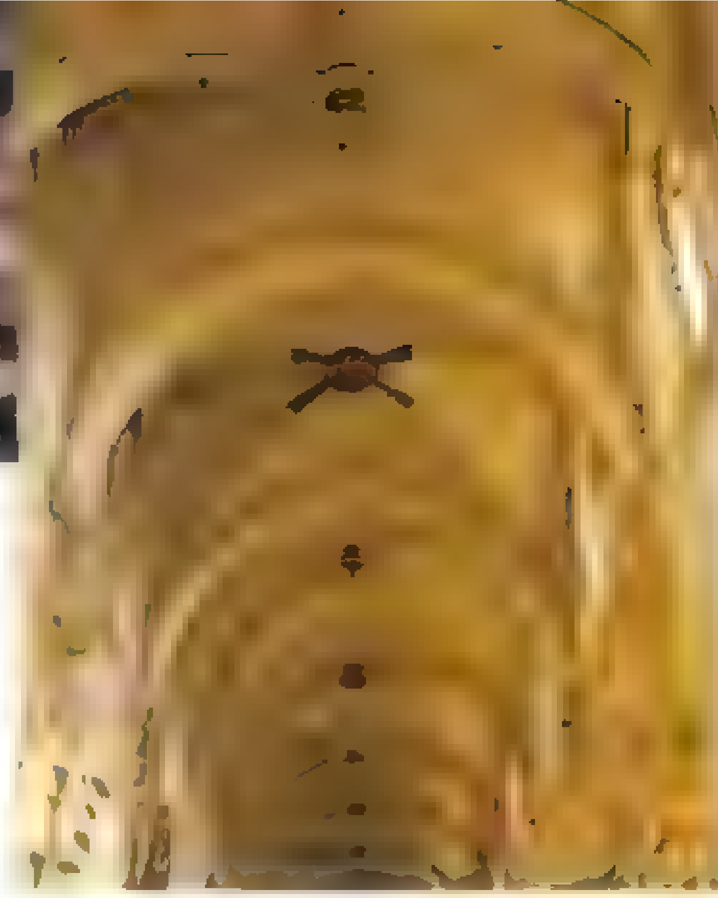
Instead of using the old rubble mix or the large massive pieces of stone used by the Romans, Muslim architects introduced small stones or bricks between the ribs, arranging them like the building of a wall in the early stages of construction.

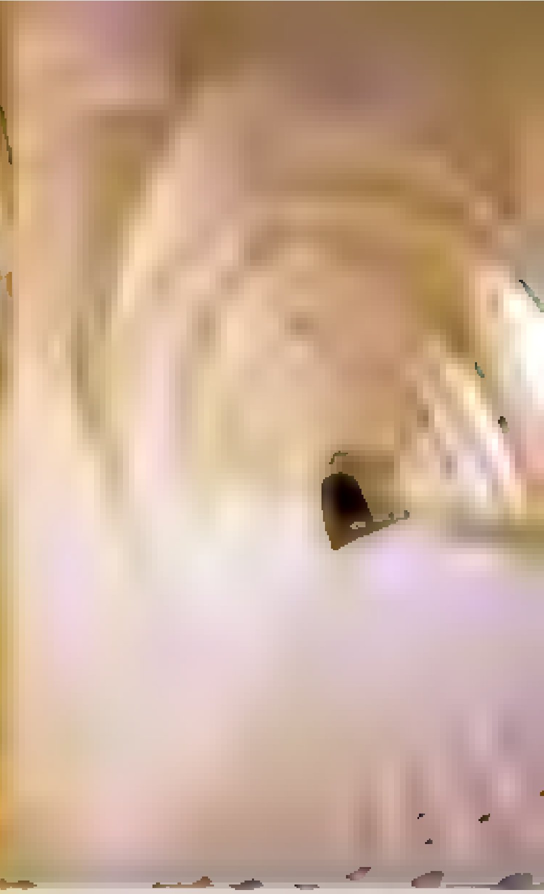
The earliest form of rib vaulting was traced to the 8^{th}-century Abbasid Palace of Ukhaydar in Iraq. This architecturally rich desert palace contains eight transverse arches and ribbed vaults. This system of ribs is also found in many of the tunnel vaults of the Ribat of Susa, built in 821–822, and these greatly influenced the cross vaults of the nave of St Philibert at Tournous, built at the end of the 11^{th} century, of St Mary la Madeleine at Vezelay (1104–1132) and of Fontenay Abbey (1139–1147). The idea of building vaults like this came from contact with North Africa, especially the town of Susa in Tunisia.

The cistern of Ramla in Palestine is made of pointed arches standing on cruciform piers of masonry, which were covered with six barrel vaults reinforced with walls. It was built by Harun al-Rashid in 789. A similar vault was built in Susa, Tunisia, in the two main mosques of Banu Fatata (834–841) and the Great Mosque (850–851). This idea then appears in the Notre Dame d'Orcival cathedral, built in the 12^{th} century in Puy-de-Dome in Auvergne, France.



Ribs of the tunnel vaults of the Ribat of Susa, built in 821–822 CE.





Left to right: Gothic type rib vaulting at Bab Mardum Mosque built at the end of the 10th century in Toledo, Spain; two examples of Gothic rib vaulting.

Gothic Rib Vaulting

As you've already read, ribbed vaults were known to the Muslims more than one hundred and fifty years before they appeared in Christian cathedrals and churches. A second type of rib, which became known in Europe as the Gothic rib, was more complex, and it first appeared in the great mosques of Muslim Toledo and Cordoba.

The ribs of Cordoba inspired European architects and their patrons to adopt them in the Romanesque and Gothic movements, and really the history of Gothic architecture is also the history of the rib and flying buttresses. To read more about the origin of the Gothic style read the 'Sir Christopher Wren' section in this chapter.

Bab Mardum Mosque in Toledo has a unique form of rib vaulting that later developed into the quadripartite vault – a vault with supporting ribs in the form of diagonal and intersecting arches, which is accepted to be the origin of the Gothic style.

This Toledo mosque was built by Muslim architects, Musa ibn Ali and Sada, between 998–1000 CE. It was in the shape of a square made up of nine small compartments, and covered with nine different ribbed cupolas or domes. Each dome is a little vault supported by intersecting arches that look like ribs thrown in the most fantastic way across each other.

French art historian Elie Lambert said that "The Arab architects ... knew and employed in their vaults, since the end of the 10th century, not only the same principle of the rib, but also the system of crossed arches, a system which became later known in France as the quadripartite vaulting."

Similar vaulting was used in another mosque which was later transformed into a house named Las Tornerias in 980. It also had nine ribbed domes combining a variety of ribs that dominated the central vault, making it an impressive looking house because it also used polychrome horseshoe and trefoil arches.

Similar ribbed domes can be seen in a large number of Spanish buildings, especially those built by the Mozarabs. They can also be seen in churches built along the route of the pilgrimage to St Jacques, also known as Compostella where these ribs decorate the domes of buildings of the Almazan church in Castille, Torres del Rio in Navarre and in the Pyrenees in Saint Croix d'Oloron and the hospital of Saint Blaise. Ribs are also found at the Templar church at Segovia and the 12th century chapter house at Salamanca.

The travelling of the ribs was down to the improvement of relations between Mozarabs and Muslims at the time of Abd al-Rahman III, as well as the great cultural and artistic achievements of his reign. In this time of peace and tolerance, art flourished. In less calm times, the capture of Toledan mosques, including Bab Mardum, must have given European artists and architects valuable lessons. The French, in particular, benefited because they were closely connected to the town after it was taken by the Spanish Christians.

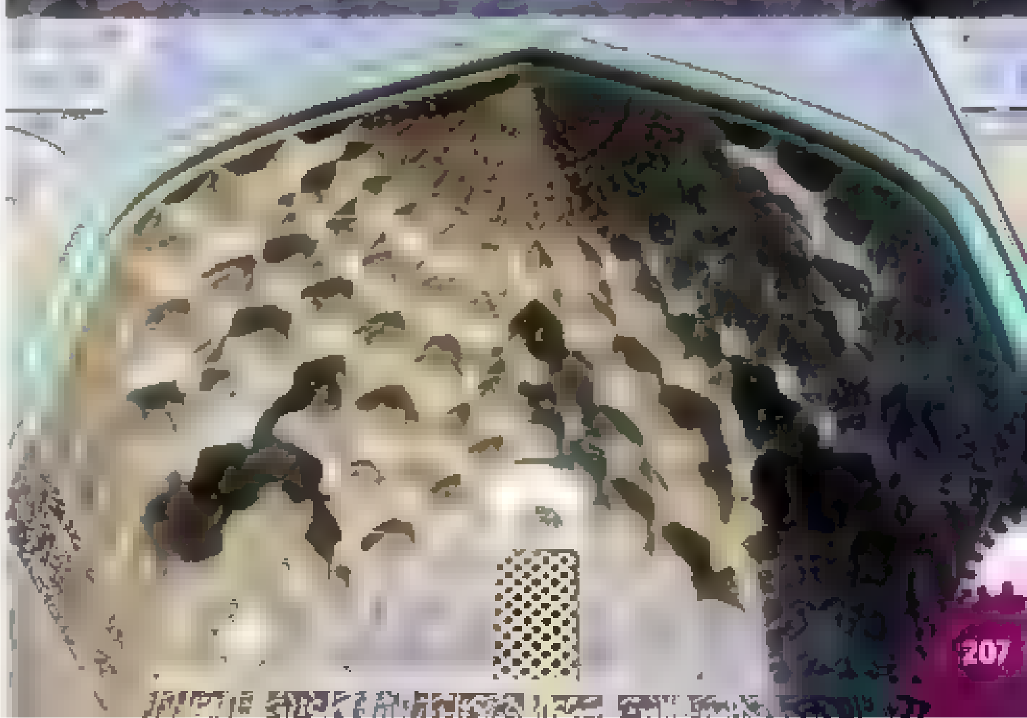
Muqarnas

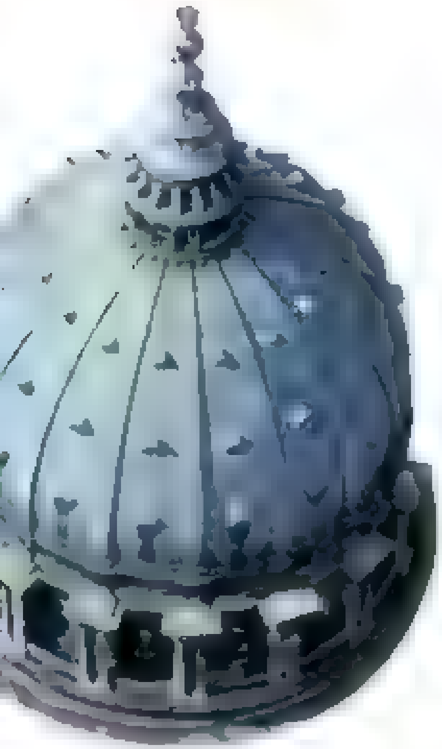
The last vault we'll visit here is the stalactite vault or *muqarnas*. They are 3-D forms made from geometrical shapes and carved into vaults, domes, niches, arches and wall corners. Developed in 10th century Persia, the idea was later spread by the Seljuks, a Turkish dynasty that ruled across Persia, Anatolia and Turkey between 1038 and 1327. By the late 11th century, the *muqarnas* became a common architectural feature all over the Muslim world.

One of the best examples of a *muqarnas* is the honeycomb of the Alhambra Palace in Granada, designed over seven hundred years ago. This honeycomb vault of the Hall of the Abencerages was organized in an eight pointed star made of a large number of interlocked small squinches of lozenge shapes, projecting from the walls in cells very like the honey comb. These symbolized the honey juice which the good believer is promised in Paradise. It was also designed with sixteen windows, two for each side of the star, which allowed in an enormous amount of light. This all helped to recreate in the Alhambra Palace a vision of the promised Paradise and its eternality, which would reward those who strove to reach it.

Below: Honeycomb dome (*muqarnas*) at Alhambra Palace in Granada, Spain

Bottom: *Muqarnas* vault at the entrance at Jame Jah Mosque in Isfahan, Iran





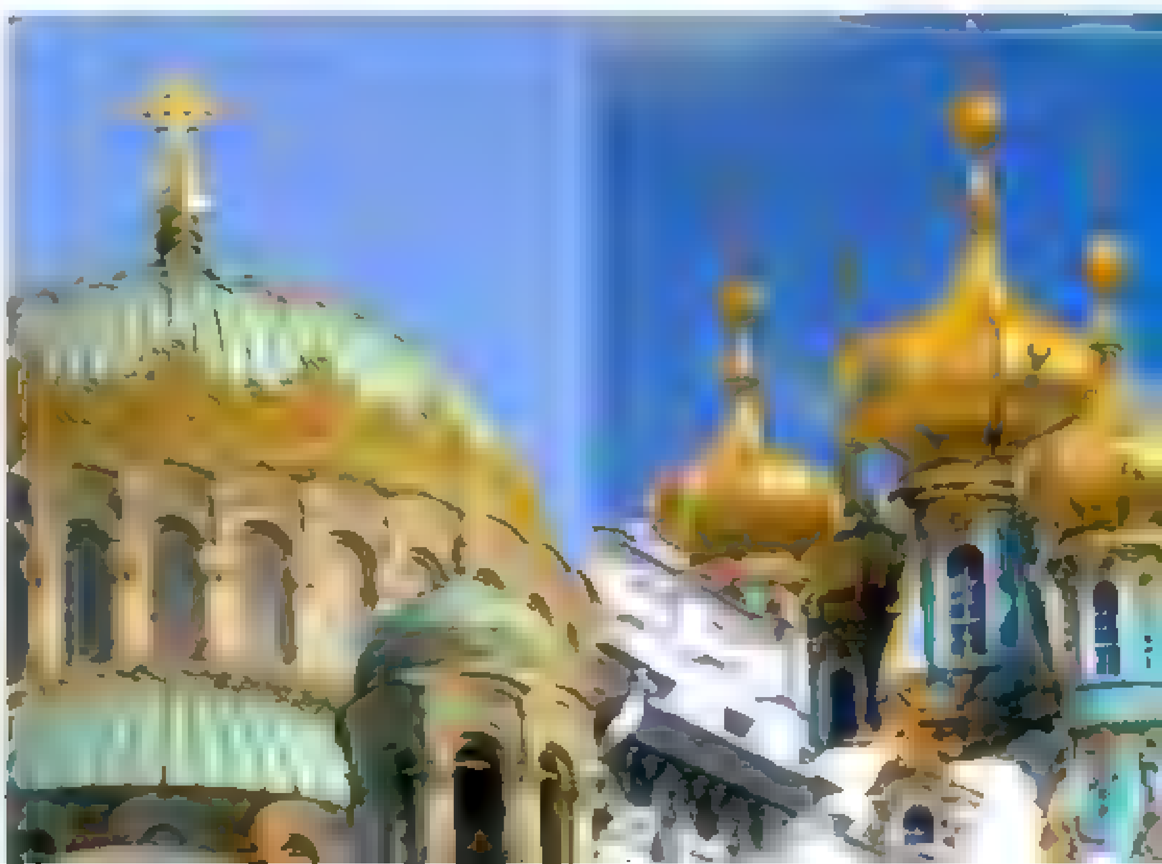
The Dome

THE DOME IS A 3-D ARCH and in Muslim (sometimes referred to as Islamic) architecture, it had two main symbolic meanings: to represent the vault of heaven and the divine dominance engulfing the emotional and physical being of the faithful. It also had a functional use, which was to emphasize particular areas, such as the nave or the *Mihrab*, while also lightening the inside of the building.

The development of domes had to overcome the problem of how to make a square bay form a domed, arched shape. The Byzantines and Persians managed this a considerable time before Muslims by using pendentives, triangular segments of a sphere placed at the corners to establish the continuous circular or elliptical base needed for the dome. These pendentives took the weight of the dome, concentrating it at the four corners where it could be supported by the piers beneath.

Muslims used them for a while, but like many other ideas they borrowed or inherited, they developed and perfected the pendentive. Eventually though, they preferred to use squinches that threw arches at the corners, creating small niches. The use of these culminated in impressive stalactite squinches or vaults known as *muqarnas* that decorated the inside of the domes. You can read more about *muqarnas* in the section on 'Vaults' in this chapter.

Right to left: The dome of the Sea Cathedral (1913) in the Byzantine style in Kronstadt; the dome of Yekaterinsky Palace at Tsarskoe Selo (Pushkin) in Russia (1717).



Semi-circular domes at the Blue Mosque in Istanbul, Turkey.

Semi-circular Dome

The most common form of the dome is the semi-circular, which is the oldest and most widespread. Early domes were small and built on the crossing before the *Mihrab*, like in the mosques of Qayrawan (670–675), and the Umayyad mosques in Damascus (705–707) and Cordoba (756–796). Over the centuries domes grew in size and number, and were later used in the centre and sometimes covering the entire roof of 'mausoleums' – tombs of founders or of holy men. Under the Ottomans, the size of domes grew to cover entire sanctuaries, surrounded by smaller domes like those in Suleymaniye Mosque.

Traditionally, domes had been made using a mixture of mortar, small stones and debris. This was all poured into timber mould that held the mortar in place until dry. A downside to this technique was that it required a lot of wood, which was not always available in arid regions. Also the masons had to wait for it to dry before moving the mould to another part of the building, so building was time consuming.

Changes had to be made to make the building process easier. First the wooden centring was replaced with brick coursing and the use of four squinches made of radiating semi-circles to produce a circular base for the dome. This brick coursing was constructed by laying an arch of bricks on edge, leaning at an angle against an end wall. Subsequent arches were laid parallel, and cemented with mortar to the flat brick faces of the previous arch until a vault or ceiling was produced.

The Muslims also used ribs, which enabled them to construct the dome in a similar way to ribbed vaulting.

Semi-circular domes at the Suleymaniye Mosque in Istanbul, Turkey.

Above left to right: Bulbous domes at the Russian orthodox church; St Paul's Cathedral in London, showing Sir Christopher Wren's adoption of the Islam inspired architecture of the duality of dome and towers.

The Bulbous Dome

The bulbous dome, or onion shaped dome, was favoured particularly by the Mughals, who spread it in Persia, the Indian sub continent and Asia. So familiar today in Moscow, Russia, bulbous domes first appeared in Europe in Venice where they were used to decorate the lanterns of the domes of St Mark's Cathedral. The domes themselves were made of wooden shells in a stilted semi-circular form, supporting the lanterns and the bulbous cupolas, and all were built in the middle of the 15th century. The domes correspond to the ogee arch or Gothic arch as a new architectural fashion after its widespread use in the Muslim world, especially Asia and Persia in the 14th century. The bulbous cupolas fit aesthetically perfectly with this form of arch.

The bulbous dome was gradually introduced to eastern Europe, firstly in wooden architecture before being built in stone, and this probably came from the Mosque of the Dome of the Rock in Jerusalem, as well as from Syria where illustrations in Umayyad mosaics have been found showing the early development of these domes.

The Duality of Dome and Minaret

Impressive mosques impose their cloud reaching minarets on our minds, counter posing the central dome on the landscape and skyline. This duality of the dome and minaret created an aesthetic appeal that was imitated by many western architects, including Sir Christopher Wren.

Sir Christopher Wren's father was the Dean of Windsor and his uncle, Mathew Wren, was the Bishop of Norwich. Wren himself graduated from Oxford in 1653, and later became Professor of Astronomy at Gresham College, London. Sir Christopher was an important mathematician, an expert in natural science theories, and a renowned architect with great respect for Muslim architecture. This he displayed by adapting numerous Muslim architectural solutions within his designs. In his greatest ever project, St Paul's Cathedral in London, this Muslim influence can be seen in the structure of the domes, in the aisles, as well as in the use of the combination of dome and tower.

The Dome of the Rock, Jerusalem (691)

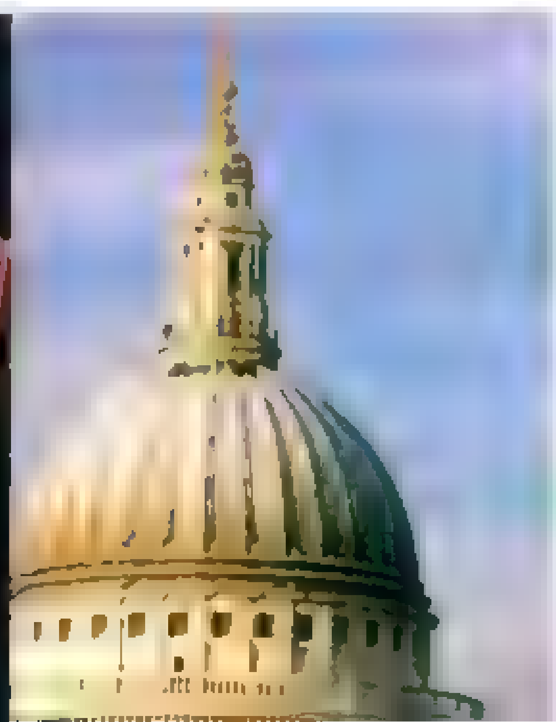
Sir Christopher Wren

THERE HAS BEEN A GREAT DEBATE about the origin of the Gothic style of architecture in Europe. Muslim architects say it came north from their designs. They are backed up by one of Britain's most famous architects, Sir Christopher Wren, who carried out over eighty architectural projects, and is renowned for his academic integrity and professionalism.

After studying and thoroughly researching the architecture in Ottoman and Moorish mosques, Sir Christopher Wren became a great appreciator of the beauty of this architecture. He investigated various structural and decorative elements of Muslim and Gothic art, and became convinced of the Muslim roots of Gothic architecture, establishing the 'Saracenic Theory'. He explains this theory himself:

This we now call the Gothic manner of architecture (so the Italians called what was not after the Roman style), though the Goths were rather destroyers than builders: I think it should with more reason be called the Saracen style; for those people (the Goths) wanted neither arts nor learning, and after we in the West had lost both, we borrowed again from them, out of their Arabic books, what they with great diligence had translated from the Greeks. They were zealots in their religion and wherever they conquered (which was with amazing rapidity) erected mosques and caravanserais in haste, which obliged them to fall into another way of building, for they built their mosques round, disliking the Christian form of a cross. The old quarries, whence the ancients took their large blocks of marble for whole columns and architraves, were neglected, and they thought both impertinent

Left to right: Sir Christopher Wren painted by Sir Godfrey Kneller, and Sir Christopher Wren's masterpiece, St Paul's Cathedral in London. Sir Christopher Wren was an admirer of the beauty of Ottoman and Moorish architecture.

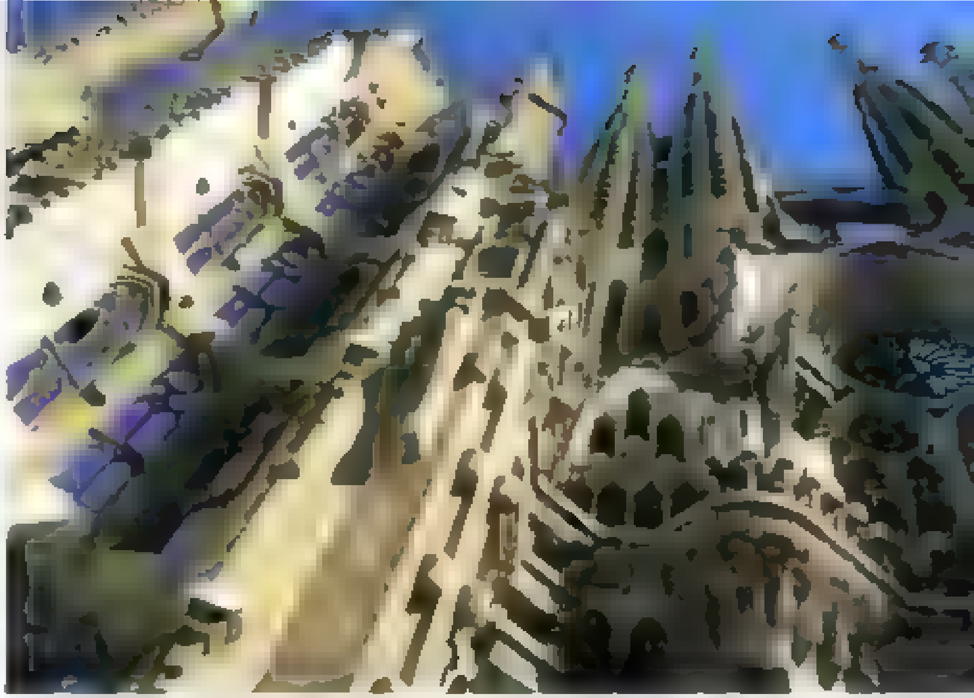


Their carriage was by camels; therefore their buildings were fitted for small stones, and columns of their own fancy, consisting of many pieces, and their arches pointed without key-stones, which they thought too heavy. The reasons were the same in our northern climates, abounding in freestone, but wanting marble.

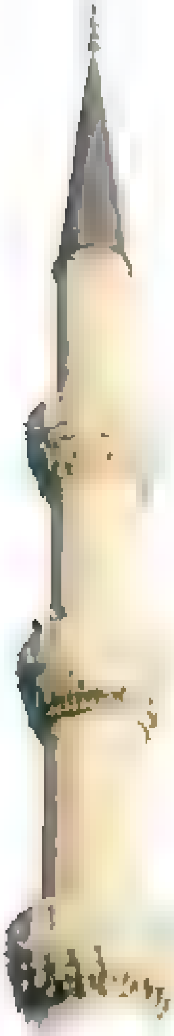
Modern Gothic, as it is called, is deduced from a different quarter; it is distinguished by the lightness of its work, by the excessive boldness of its elevations, and of its sections, by the delicacy, profusion, and extravagant fancy of its ornaments. The pillars of this kind are as slender as those of the ancient Gothic are massive: such productions, so airy, cannot admit the heavy Goths for their author; how can be attributed to them a style of architecture, which was only introduced in the tenth century of our era? Several years after the destruction of all those kingdoms which the Goths had raised upon the ruins of the Roman empire, and a time when the very name of Goth was entirely forgotten. From all the marks of the new architecture it can only be attributed to the Moors, or what is the same thing, to the Arabian or Saracens, who have expressed in their architecture the same taste as in their poetry; both the one and the other falsely delicate, crowded with superfluous ornaments, and often very unnatural; the imagination is highly worked up in both; but it is an extravagant imagination, and it has rendered the edifices of the Arabians (we may include the other Orientals) as extraordinary as their thoughts. If any one doubts of this assertion, let us appeal to any one who has seen the mosques and palaces of Fez, or some of the cathedrals in Spain, built by the Moors: one model of this sort is the church of Burgos; and even in this island there are not wanting several examples of the same: such buildings have been vulgarly called Modern Gothic, but their true appellation is Arabic, Saracenic, or Moresque.

This manner was introduced into Europe through Spain; learning flourished among the Arabian all the time that their dominion was in full power; they studied philosophy, mathematics, physics, and poetry. The love of learning was at once excited, in all places that were not at too great distance from Spain, these authors were read, and such of the Greek authors as they had translated into Arabic, were from thence turned into Latin. The physics and philosophy of the Arabians spread themselves in Europe, and with these their architecture: many churches were built after the Saracenic mode; and others with a mixture of heavy and light proportions; the alteration that the difference of the climate might require was little, if at all, considered. In most southern parts of Europe and in Africa, the windows (before the use of glass) made with narrow apertures, and placed very high in the walls of the building, occasioned a shade and darkness within side, and were all contrived to guard against the fierce rays of the sun; yet were ill suited to those latitudes, where that glorious luminary shades its feebler influences, and is rarely seen but through a watery cloud.

Discussion of the Islamic Origin of the Gothic Style taken from Parentalia: or, Memoirs of the family of the Wrens, viz. *by Mathew Bishop in 1750*



Cathedral of Sagrada Familia, Barcelona, Spain



The Spire Tower

MINARET COMES FROM THE ARABIC WORD *MANARAH*, which means 'lighthouse', but not in the meaning of sea lighthouse as some writers thought. It has rather a symbolic significance referring to the light of Islam which radiates from the mosque and its minaret.

By the 8th century, in the Great Mosque of Damascus the minaret had become an essential feature of Muslim religious architecture. Minarets have two main parts; the lower part has a strong blind base with little or no decoration at all, and the higher part is very graceful and richly decorated. This sectioning of the tower is seen in many English towers like Sir Christopher Wren's St Mary le Bow Tower.

The earliest surviving Muslim tower is the Qal'at of Beni Hammad, which was built in 1007 in eastern Algeria. With its huge size expressing the power of Beni Hammad, the tower was used as a watchtower as well as a minaret. It was richly decorated, with openings providing light and reducing the weight of the structure. Various types of arches were used on the frames of these windows, including trefoil, cinquefoil, semi-circular and polylobed arches.

It was features like these that later formed the character of the Romanesque and Gothic towers of the West. Good examples of this are Church of St Abbondio, Como, Italy (1063–1095), Church of St Etienne, Abbaye aux Hommes at Caen, France (1066–1160), and St Edmund at Bury in England (1120). In all cases, the influence of Qal'at Beni Hammad is unquestionable, and the European trade links with North Africa must have been responsible for its transfer.

Qal'at of Beni Hammad is the earliest surviving Muslim tower, built [illegible] 1007 in Algeria. Features it displayed, rich decoration and arch designs of the upper sections, were later found in the Romanesque and Gothic towers in Europe.

In Europe the tower first appeared in the 10th century Romanesque period, but became associated with Gothic architecture. Some people believed the tower came from the minaret, as it began appearing in European castles and gatehouses as the crusaders came home.

Spires were never used until the minaret was built, and in England there was no spire before 1200, the first being that of St Paul's Cathedral in London, finished in 1221. (This was later destroyed by lightning in 1561 and by the Great Fire of London in 1666, to be rebuilt by Wren in 1710.) The minarets of al Jeyushi Mosque in Cairo, built in 1085, were particularly influential in Italy and England. Square-shaped minarets continued to influence European towers, as seen in Palazzo Vecchio at Piazza la Signoria (1299–1314) in Italy. Piazza Ducale in Italy is particularly striking when it is compared to the Umayyad Mosque in Damascus. The Italian tower has the same gradual progress of the square-shaped tower and the same bulbous dome at the top end. The arcade of the cloister which the tower emerges from shows a similar visual and structural combination to the one used in the Umayyad Mosque.

This graceful, circular form of minaret was also imitated in Germany in buildings like the Holy Apostles Church in Cologne (1190), in Amins Cathedral (1009–1239), and in Worms Cathedral (11th to 13th centuries) in Rhineland. The Cologne tower has particularly breakneck proportions as it soars into the air.

Some people believed the tower came from the minaret, as it began appearing in European castles and gate houses as the crusaders came home.

Above left: Church of St Abbondio, Como, Italy (1013).

Left: Minaret at the Umayyad Mosque in Damascus (706–715).

Muslim Architecture in the World

A LOT OF MUSLIM ARCHITECTURE reached Europe through captured artists, and the fully Romanesque style appeared at the same time as the first counter-campaign against the Muslims in Spain and in the Holy Land. One who was taken prisoner was Lalys and his new master was Richard de Grandville of England, who had Lalys design the abbey of Neath in South Wales in 1129. Lalys then became the architect of Henry I.

The Normans brought a lot to English architecture in their 1066 invasion after sweeping across Europe in a conquering wave. They also occupied Sicily where they made contact with Muslims. It was here that their barbarity abated and they became great builders instead of destroyers. In fact, as Rageh Omar from the BBC's *An Islamic History of Europe* says: 'Architecturally little remains in Sicily from the Muslim time and the buildings that look Islamic aren't. They were built in the 11th century by the Norman conquerors who were fascinated by Arabic culture. The 12th-century Norman king Roger II of Sicily was particularly passionate about Muslim architecture. He was also fluent in Arabic.' It was these, architecturally 'Islamized' Normans who later played a leading part in building Europe. Gothic style architecture also developed under these Norman kings.

Edward I sent ambassadorial exchange missions to Persia to make allies of the Mongols, who had taken the region and were the enemies of the Muslims. This mission was led by Geoffrey Langley in 1292 and lasted a year. It included Robertus Sculptor, who is thought to have brought back with him a number of ideas, like the ogee arch, which were then introduced to English architecture at the end of the 14th century.

'The 12th-century Norman king Roger II of Sicily was particularly passionate about Muslim architecture. He was also fluent in Arabic.'

Rageh Omar from the BBC's *An Islamic History of Europe*

Palatine Chapel, Palermo, Sicily, designed and decorated by Muslim artists in the reign of Norman king Roger II

Left to right: The 12th century circular Temple Church in London, originally built on the same centralizing style as the Dome of the Rock mosque in Jerusalem built in the 7th century; the Taj Mahal built in 1630 Agra, India

Later Edward II had good contacts with Persia, and his crusading experience plus his marriage to Eleanor of Castille provided further contact with Muslim Spain. These contacts are commemorated in English folklore by Morris dancing, first known as Morisco. The Muslim contacts also led to Tudor architecture, such as the star polygon plan at Windsor, in the tower of Henry VII and in the windows of his chapel, and the turrets of Wolsey's great gate at Oxford, now called Tom Tower.

Others to take back ideas were pilgrims and artists visiting Egypt, like Simon Simeon and Hugh the Illuminator. Both were Franciscan who visited the Holy Land in 1323, and who would have passed through Egypt and seen the Mausoleum of Mustapha Pasha (1269–1273) in Cairo. This had Muslim perpendicular decoration that became a common feature of Gothic architecture in the UK.

The chapels of the Knights Templar Order, founded by nine French knights in Jerusalem in 1118 after the first crusade, were built with a centralizing form, which was derived from the city's Dome of the Rock Mosque. This form of church later spread west and can be seen in the circular Temple Church of 1185 in London. The rotunda, which is late Norman, and the Gothic choir, built in 1240, have a number of common features, and they are both subject to the same geometric system. Some western scholars insist that this system came to Europe and France from the Greeks, especially Plato and Vitruvius, but we have to wonder at this perfect timing. Why didn't the French rediscover Plato earlier or later? It seems a real coincidence that the features appeared in Europe at a time when they were very evident in Islamic structures visible to crusaders, other travelers and traders.

Another famous building which many do not realize is Islamic is the Taj Mahal, in India, built by the Mughal sultan Shah Jahan in memory of his wife Mumtaz Mahal who died while giving birth to their fourteenth child. This is called the 'teardrop on eternity' and was finished in 1648, after using precious and semi-precious stones as inlay and huge amounts of white marble that nearly bankrupted the empire. The Taj Mahal is completely symmetric – except for the tomb of the sultan which is off centre in the crypt room below the main floor.

More really amazing Islamic architecture includes the Cathedral Mosque in Cordoba, Spain and the Alhambra Palace in Granada. All of these still fascinate people today, and the Taj Mahal just pips the Alhambra at the post for the most visitors with 3 million a year, while the Alhambra draws 2.2 million or 6,000 people a day.

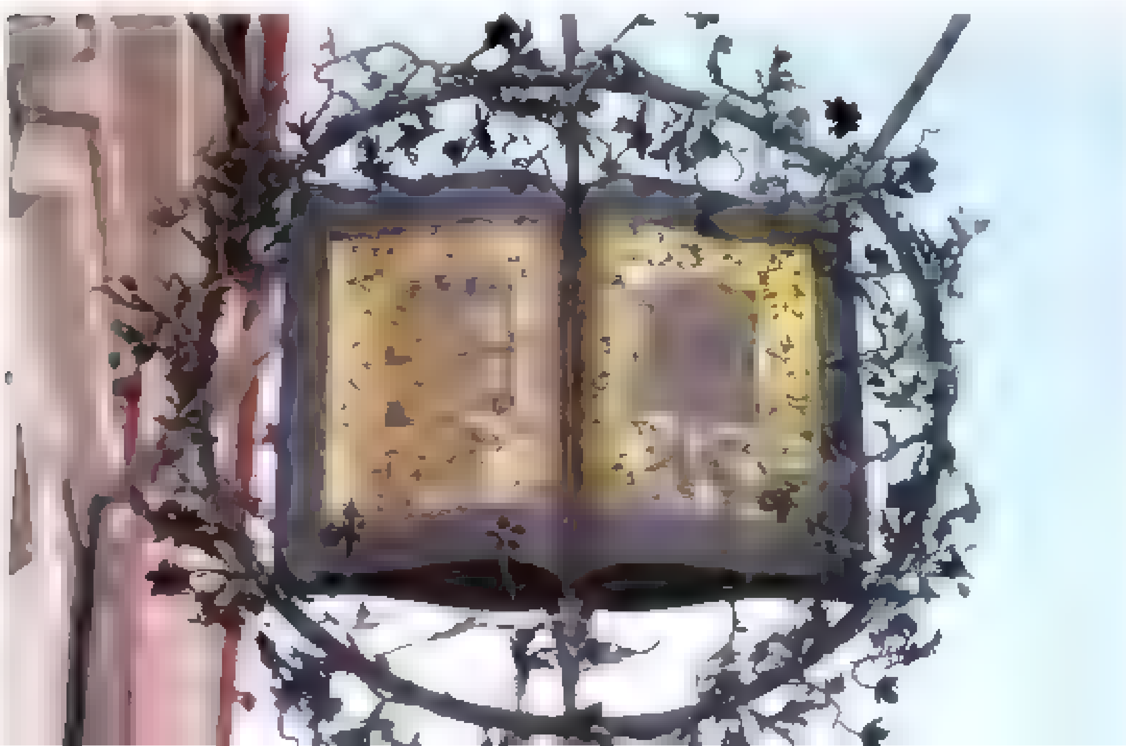
Bookshops

THE IDEA OF A BIG BOOKSHOP having a coffeeshop and regular speakers is not new. The celebrated bookshop of Ibn al-Nadim, the 10th century bibliophile and bookseller, was said to be on an upper story of a large building where buyers came to examine manuscripts, enjoy refreshments and exchange ideas. In the Muslim world a thousand years ago, as well as there being massive public and private libraries, there were also bookshops. An average bookshop contained several hundred titles but larger bookshops had many more on offer.

Al-Fihrist, the catalogue of books that Ibn al-Nadim sold, listed more than sixty thousand titles on an unlimited range of subjects. The first section of the first chapter of *al-Fihrist* was devoted to various styles of writing, including Chinese, qualities of paper, and 'excellencies of penmanship' and 'excellencies of the book.' After this was a whole range of topics including language and calligraphy; Christian and Jewish scriptures, the Quran and commentaries; linguistic works; histories and genealogies, official government works, court accounts, pre-Islamic and Islamic poetry; works by various schools of Muslim thought; biographies of numerous men of learning, Greek and Islamic philosophy, mathematics, astronomy, Greek and Islamic medicine; literature; popular fiction; travel (India, China and Indochina), magic and miscellaneous subjects and fables.[1]

With paper, *warraq* in Arabic, came the profession of *Warraq*. The title *Warraq*

In the past, bookshops put up signs to attract customers.



'The vast book publishing industry in the Western world is truly awesome and certainly cannot be praised enough. But this … cannot eclipse an equally awesome, sophisticated and wide-ranging publication industry that first grew in the Muslim civilization around the middle of the 8th century, almost one thousand years before books appeared in the same quantity and quality in the West….

Ziauddin Sardar, British writer, broadcaster and columnist

has been used for paper dealers, writers, translators, copiers, book sellers, librarians and illuminators. The profession of the *Warraqeen* is generally believed to have started shortly after the introduction of the art of papermaking in the Muslim world, which you can read more about in the Market chapter. Baghdad was probably the first major city where the *warraqi* bookshops first appeared, and as the manufacture of paper spread, the number of these bookshops increased dramatically throughout the Muslim world.

Kutubiyyin is a Moroccan name for bookbinders or book merchants, who set up their bookshops, libraries and copyists and scribes in a district of 12th century Marrakech, Morocco. This district was a street with a hundred bookshops and libraries, fifty on each side. Such activity reached its zenith during the reign of Yaqub al-Mansur, who constantly encouraged the spread of book printing and promoted general reading activity. There's a story that tells how one day a celebrated literate man named Ibn al-Saqr who, during the eight months siege of Marrakech, left his house to buy some food for his hungry family, but ended up spending all his money on buying a book instead.

To read more about the importance of books and learning, see the 'Library' section in the School chapter.

'Buy books, and write down knowledge, for weather is transitory, but knowledge is lasting.'

Arabic Proverb

Public Baths

SPAS AND HEALTH CLUBS have sprung up over the world today, letting all luxuriate in their steam and fine soaps, but this was not always the case. In the so called 'dark ages' of Europe, the bath was particularly unfashionable.

After the collapse of Rome, the Romans and most of their mod cons disappeared. For the Romans, the bath was an elaborate building complex, complete with a medium heated room or *Tepidarium*, a hot steam room or *Caldarium*, and a room with a cold plunge pool or *Frigidarium*. In some of the larger baths there were other sections with changing rooms called *Apodyterium*, a reading room and sports area. But these treatment centres were for the rich and political elite only.

While these baths fell into disrepair as the Roman Empire lay in tatters, on the other side of the Mediterranean the Arabs, who had been under Roman rule in countries like Syria, inherited the tradition of using the bath. Instead of the waters becoming stagnant as the Romans left, the Arabs and then Muslims gave them special promotion because of Islam's emphasis on cleanliness, hygiene and good health. Reporter Rageh Omar presenting the BBC's *An Islamic History of Europe* said that there were thousands of *hammams* in a city of quarter of a million.

The bath house, or *hammam*, was a social place and it ranked high on the list of lifes

'Indeed, God loves those who turn to Him constantly, and He loves those who keep themselves pure and clean.'

Quran (2:222)

Men relax inside Cagaloglu Hamami, a Turkish bath [illegible] around 1[illegible]

essentials. The Prophet Mohammad (pbuh) said 'cleanliness is half the faith'. *Hammams* then were elaborate affairs with elegant designs, décor and ornamentation. Under the Mamluk and Ottoman rule, they were especially sumptuous buildings in their rich design and luxurious decorations, furnished with beautiful fountains and decorative pools.

The *hammam* was, and still is, a unique social setting for Muslim communities, playing an important role in the social activities of the community. As an intimate space of interaction for various social groups, it brought friends, neighbours, relatives and workers together regularly to undertake the washing ritual in a partying atmosphere. Group bonds strengthened, friendships rekindled and gossip was swapped. This therapeutic ritual was carried out by both men and women at separate times, with the women usually bathing in daylight and men in the evening and night.

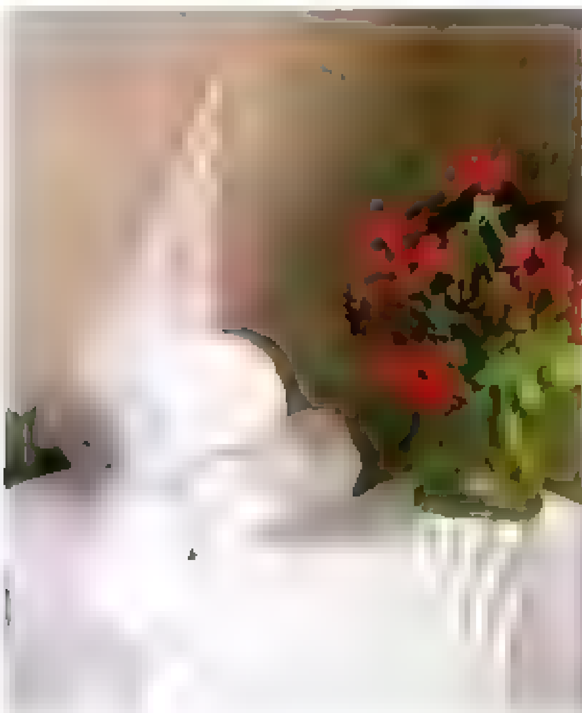
The intrigue and sociability at the *hammam* didn't just stop at scrubbing and gossip, as traditionally the setting played a significant role in matchmaking. In conservative communities such as those of North Africa, women who were looking for suitable brides for their sons would go to the *hammam*. Here they had the perfect opportunity to have a closer look at the bride to be and select the most physically fit. However, this tradition is gradually losing its popularity as arranged marriages in these societies are becoming increasingly rare.

It is also customary in many parts of the Muslim world for the new bride to be taken with her friends to the *hammam*, where she is prepared, groomed and adorned in stylized designs with *henna*, the herbal paste that leaves a reddish-brown colour on the hair, hands and feet. The groom is also escorted there the night before he meets his bride.

The art of bathing in *hammams* is guided by many rules, such as: men must always be covered in 'lower' garments, and women are forbidden to enter if men are present. Quite a few books have been written about this, like

Baghdad bathhouses were '... the most sumptuous of baths ... that ... appear to the spectator to be black marble.... Inside each cubicle is a marble basin fitted with two pipes, one flowing with hot water and the other with cold.'

Ibn Battuta, 14 century traveller



Left: Exterior of public bath in Tbilisi, Georgia

Right: 16th century Turkish manuscript showing a public bath owner as part of a procession on craftsmanship that paraded in front of Sultan Murad III on the occasion of the circumcision of his son

Al-Hammam and its Manners from the 9th century by Abu Ishaq Ibrahim ibn Ishaq al-Harbi.

The sophistication of the bathing process in 14th century, Baghdad involved private chambers and three towels, causing Ibn Battuta to say 'I have never seen such an elaboration as all this in any city other than Baghdad.'

As we have said, the bath was known to Europe in Roman times, but it fell out of use as Rome fell. In the 1529 work by Sir John Treffy's *Grete herbal*, we can read about bathing attitudes: 'many folke that hath bathed them in colde water have dyed'.

Hundreds of years later, baths were rediscovered during the Crusades when the crusaders encountered Muslim baths in Jerusalem and Syria. This rediscovery was brief, though, as the church banned their use, partly because they belonged to 'the culture of Muslims, the infidels' and partly because of the spread of adultery and bad sexual habits and diseases following their immoral use because the manners of the *hammam* were not followed by the Europeans.

By the 17th century, *hammams* were rediscovered when Europeans met Turkish baths. This was at the same time that it became fashionable to use oriental baths and Levantine flowers. In England, in places such as London, Manchester and Leeds, this was a real craze. The first Turkish bath or 'bagnio' was opened as early as 1679 off Newgate Street, now Bath Street, in London and was built by Turkish merchants. Turkish baths were also built in Scotland, in Edinburgh, where the famous Drumsheugh Baths were designed by John Burnet in 1882. The elaborate nature of the bath was recreated in all its glory, as this contained a suite of Turkish baths with a dome supported on a brick and stone structure, with geometrical lattice windows in frames of horseshoe arches. Meanwhile, the façade was decorated with an elegant Moorish arcade with iron grilles in a geometric pattern.

So, it's believed that the *hammam* is the origin of most of the health and fitness clubs and retreat centres spread over the modern world. Sweating flushes out impurities and helps us to lose fat. Steam and hot water increase blood circulation and raise the pulse and metabolic rate. The relaxation in the *al-Barrani* (translated as 'the Exterior'), the equivalent to the rest room or Roman *Apodyterium*, lets the body rest and benefit from all the previous exercises, while the social interaction and the friendly atmosphere benefits all.

Turkish bath in the city of London, UK. In the shadow of Sir Norman Foster's renowned building popularly known as the 'London Gherkin' stands the exterior of an old Turkish hammam. The building is now a [illegible].

The Tent

TENTS THESE DAYS conjure up images of rain drenched campsites or beautiful wedding marquees. They have a practical and social function, are large or small, and so remain true to their roots from the time when Muslims and Bedouin Arabs used them as a shelters and meeting places.

They could be elaborately decorated royal structures in a sultan's ceremonies, which were beautifully coloured affairs with silk crowns and a raised section to add extra splendour and majesty. Inside were comfortable seats and canopies, colourful carpets, plus some of the sultan's favourite weapons and toiletries. The tent followed the sultan in his travels for war, hunting trips and other visits and ceremonies.

Europeans fell in love with the Ottoman tent the first time they set eyes on it. In the beginning it was reserved for royals and the rich, for grand parties and royal ceremonies. The French king, Louis XIV, was its greatest admirer and he had many ceremonial tents, *a la Turque*. These usually accompanied extravagant processions and royal parties with firework displays. His fashion statements caught on with the rest of the royal households of Europe who didn't want to be left out of the latest craze and the tent dominated most of the 17th century.

Louis had a real interest in the Islamic world, and he gathered knowledge about it through travellers like Francois de la Boullaye-le Gouz and Jean Baptiste Tavernier. La Boullaye even arrived at the Royal court wearing Persian dress. Louis also had in his service two renowned Arab linguists, Laurent d'Arvieux and Antoine Galand.

Far right: This Ottoman manuscript is a memoir of the military movement during an expedition of Suleyman the Magnificent against Hungary. The tents of different colours possibly refer to different regiments pitched around River Ibri of Mitrovica, located in the Leposavic municipality of Kosovo. The writing insets give us a snapshot of the camp on 23 Safar 950 AH (or 24 May 1543), and tells us they moved six miles in two days.

in Vauxhall Gardens, England, and one of these tents was built in 1744 and it had a dining area with fourteen tables. The two most famous Turkish tents in England were built around 1760 in the gardens of Painshill, Surrey, owned by the Honourable Charles Hamilton, and Stourhead, Wiltshire, owned by Henry Colt Hoare. John Parker did a watercolour illustration of the tent at Painshill after he visited it in 1763.

The site of the tent at Stourhead was originally for a mosque with minarets, but the idea changed into a tent that was dismantled in the 1790s. A third Turkish tent was built at Delgany, Wicklow, Ireland by David la Touche in the late 18th century, but tents never really caught on there because of the weather.

European imitation of Turkish tents also took on a lot of the Islamic architectural styles, and in the 18th century architect John Nash produced a "total exotic exterior effect" of a Royal Pavilion, which greatly pleased his Royal patrons. He used the oriental scenery described by 18th century landscape painter Thomas Daniell. Daniell was also the author of *Oriental Scenery*, and was hired as a consultant to help design a British residence with such features as a bulbous dome with corner *chattris* and overhanging eaves, cusped arches and pinnacles. It was Daniell who inspired Nash, who was commissioned by George IV to remodel an unfinished structure at the Royal Pavilion in Brighton. So he combined bulbous domes with concave shaped roofs, imitating the Turkish caliphs tents that covered the banqueting and music rooms of the building. He also used minaret like structures to disguise the chimneys.

This type of tent still exerts a strong influence, and one still survives at Canterbury Park in Hampshire. The roof of the Rotunda in Vauxhall Gardens was a tent with blue and yellow alternating stripes, supported by twenty pillars. English writer Nathaniel Whittock in 1827 described it as a Persian Pavilion.

Other famous people to enjoy and own tents included the Empress Josephine, who had a Muslim tent room at Malmaison, and King George IV often dined there. Then the Marquess of Hertford, nicknamed the Caliph, had a tent room made for him by Decimus Burton at St Dunstans House. This burned down in 1936 and was rebuilt in a different design.

A 16th century miniature from the *Hunername* by Mehmed Lokman showing the accession to the throne of Selim II. Note the various uniforms worn by the ranks of the government. A senior officer is waiting to kiss the hem of the Sultan's clothes [illegible] unacceptable [illegible]. Kissing the hem is an Ottoman tradition to demonstrate loyalty and obedience.

From Kiosk to Conservatory

WHAT WE NOW THINK of as a garden summerhouse and the bandstand in the local park or town square came from what was called a Turkish kiosk or *Koshk*. This was a domed hall with open and arched sides, attached to the main mosque under the Seljuks. Gradually it evolved into the summerhouses used by Ottoman sultans.

The most famous of these kiosks were the Cinili Koshk and Baghdad Koshk. The Cinili Koshk was built at the Topkapi Palace, Istanbul, in 1473 by Muhammad al-Fatih and had two storeys topped with a dome, with open sides overlooking the gardens of the palace. The Baghdad Koshk was also built at the Topkapi Palace in 1638–39, by Sultan Murad IV. This also had a dome, and the view it gave onto the gardens and park of the palace, as well as the architecture of the city of Istanbul, was amazing.

... European monarchs ... brought it to Europe.

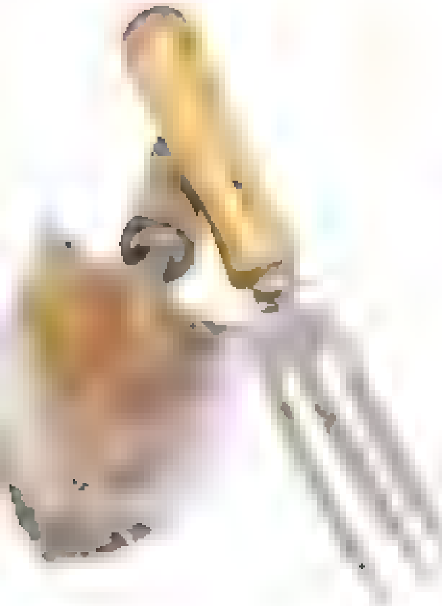
Lady Wortley Montagu, the wife of the English ambassador to Constantinople, wrote a letter on 1 April 1717 to Anne Thistlethwayte mentioning a '*chiosk*', describing it as 'raised by nine or ten steps and enclosed with gilded lattices', but it was European monarchs who brought it to Europe. The king of Poland particularly liked it, as did the father-in-law of Louis XV, Stanislas of Lorraine, who built kiosks for himself based on his memories of his captivity in Turkey. These kiosks were used as garden pavilions for serving coffee and

A kiosk at Topkapı Palace in Turkey named the Baghdad Koshk (built in 1639) by Sultan Murad IV after his conquest of Baghdad. It contains a [illegible] covered by a dome with a long chimney for expelling smoke from the fire.

beverages, but later were converted into the bandstands and tourist information stands decorating many European gardens, parks and high streets.

All good designs evolve, and in this case the kiosk evolved into what we now call conservatories, glass rooms built in gardens or on the sides of many European houses. The earliest conservatories were those made by Humphrey Repton for the Royal Pavilion at Brighton. These were sumptuous affairs, with corridors connecting the Pavilion to the stables, and with a passage of flowers covering the glass. They also joined the orangery, a greenhouse, an aviary, an enclosure for pheasants and hothouses. The pheasantry area was particularly Muslim in concept, and it was an adaptation of the kiosks on the roof of the palace in the Fort of Allahabad in India.

16th century miniature of Sultan Murad III and his sons sitting in a kiosk from the Shahanshahnama, illustrated by Mirza Ali b Hacemkund ali



Gardens

SUNNY DAYS ARE SPENT CUTTING THE GRASS while hoping it doesn't rain too much, again. Insects are dealt with, moles are moved on and birds are made to feel welcome. Lawns, with their herbaceous borders, dominate many gardens in Europe, especially in the UK. Back in the Middle Ages though, gardens in Europe were limited to the courts of nobles or monasteries, and their main use was for herbs, vegetables and some fruits for self-sustenance.

For Muslims, gardens have always been a constant source of wonder and enchantment, because plants, trees, animals, insects and all of nature are a blessed gift of Allah and a sign of His Greatness. Islam permits us to use, enjoy and change nature, but only in ethical ways, so Islamic gardens were designed to be sympathetic to nature, and gardens to this day enjoy an elevated status in a Muslim's mind.

Gardens such as Eden were repeatedly described in the Quran as places of great beauty and serenity, and as ideal places for contemplation and reflection. These heavenly paradises were recreated and spread across the Muslim world, from Spain to India, mainly from the 8th century onwards. About one hundred years later, the Abbasids innovated designs of their own. From then on, gardens with geometrical flowerbeds, shallow canals and fountains were built everywhere in Islamic Persia, Spain, Sicily and India to provide peaceful seclusion from the outside world. Just a look at the Alhambra in Granada, Spain or the Taj Mahal in India proves this.

'Gardens under which rivers flow to dwell therein and beautiful mansions in gardens of everlasting bliss.'

Quran (9:72)

Right: 17th-century manuscript showing Sultan Babur holding a plan, watching his gardeners measuring flower beds.

Below left: 16th-century miniature showing Suleyman the Magnificent. The Serail gardens in Turkey of Suleyman the Magnificent cultivated tulips

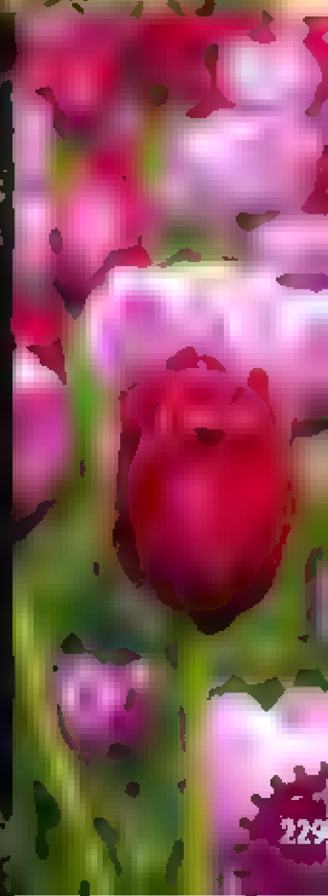
Gardens were not only for meditation; many had a practical function, and Arab rulers collected plants. These kitchen gardens not only supplied food, they also gave rise to a type of Arabic poetry known as the *rawdiya*, the garden poem, which conjured up the image of the Garden of Paradise.

It was in Toledo in 11th-century Muslim Spain, and later in Seville, that the first royal botanical gardens of Europe made their appearance. They were pleasure gardens, and also trial grounds for the acclimatization of plants brought from the Near and Middle East. In the rest of Europe these gardens appeared about five centuries later in the university towns of Italy. Today, the influence of the Muslim garden can be seen all over Europe, from the Stibbert garden in Florence to the Royal Pavilion in Brighton, England.

It wasn't just the concept of gardens that spread with the Muslims, because they also brought flowers from the East that you can now buy down at the local gardening centre. Such travellers include the carnation, tulip and iris.

Some people believe the word 'tulip' comes from *Dulband* which means turban, as people used to wear it on their turban. Others say the word 'tulip' is an anglicized version of *dulab*, which is Farsi for tulip. From Persia the tulip reached Constantinople through ambassadorial gift exchange, where it was largely planted in the Serail gardens, especially in the Topkapi Palace in Istanbul.

The tulip's voyage into Europe has been like a well thought out invasion of perfume and colour. It first stepped out in 1554 with Count Ogier de Busbecq, the Hapsburg (Austrian/Hungarian) ambassador to Suleyman the Magnificent, when he took one with him. About ten years later, it reached its now famous 'home' in Holland. The Duke of Sermoneta,



'Early Muslims everywhere made earthly gardens that gave glimpses of the heavenly garden to come. Long indeed would be the list of early Islamic cities which could boast huge expanses of gardens. To give only a few examples, Basra is described by the early geographers as a veritable Venice, with mile after mile of canals criss-crossing the gardens and orchards; Nisbin, a city in Mesopotamia, was said to have 40,000 gardens of fruit trees, and Damascus 110,000.'

Watson A M 1983: *Agricultural Innovation in the Early Islamic World*, Cambridge University Press

Francisco Caetani, was a tulip collector and had 15,147 in his Italian garden in the 1640s. The Huguenots, France's persecuted Protestants, took the tulip with them into different countries as they ran away. Finally in the 1680s an Englishman called Sir George Wheler brought it to Britain from the Serai gardens of Constantinople.

The carnation and iris were less well travelled as flowers but popular in decorating Persian and Turkish ceramics. With its fan shape, the carnation was a successful combination with the tulip in Iznik pottery. This design was also copied in European decoration and appeared in a number of Lambeth chargers, ceramics produced at Lambeth, England, dating from 1660–1700.

The iris was used in horizontal and circular forms by Persian potters, particularly under the Safavid dynasties in the 16th and 17th centuries. These then went on, like the carnation, to influence European designs like the Bristol delftware ceramics.

The British love gardening and still cultivate these flowers, and flower shows are booming. One of the biggest of these shows is Chelsea and if these figures are anything to go by, then gardening and gardens are far from fading: each show costs about £3 million and over show week 60,000 pieces of cake, 110,000 cups of tea and coffee, and over 28,000 rounds of sandwiches are sold as the keen gardeners sustain their appetites for all things green.

Fabulous Fountains

FOUNTAINS SOOTHE THE TWO SENSES of sight and sound at once. They provide a calming atmosphere and screen out urban noises like traffic, road drills and barking dogs in today's ever noisier world. They also provide privacy, with quietly spoken words not reaching others in the vicinity, and are a bath for birds.

Water features are an integral part of gardens today, just as they were a thousand years ago in the Islamic world. Then they were a display of ultimate wealth, as water was scarce, and a water display was regarded as a thing of wonder. Fountains became cornerstones of Islamic art and architecture and one of the best examples is the fountain in the Lion Gardens of the Alhambra, Spain, which is nearly a thousand years old. It was commissioned by Sultan Mohammed V for the Court of Lions, and built between 1354 and 1359.

The fountain has a round basin, encircled by twelve lions carved from marble that originally would have been richly painted, mostly in gold. The lions represent the twelve signs of the zodiac and the twelve months. Water was carried to them by aqueducts from the surrounding mountains, and it flowed from their mouths via an elaborately timed system of channels in the floor.

Each hour one lion would produce water from its mouth, giving the impression of twelve months elapsing as though they were twelve

'Surely the God-fearing shall be among gardens and fountains.'

Quran (51: 15)

hours. The sense of timelessness created was [illegible] because the magnificent palace was considered as a paradise on earth and time in paradise is non-existent as the dwellers live in eternal happiness.

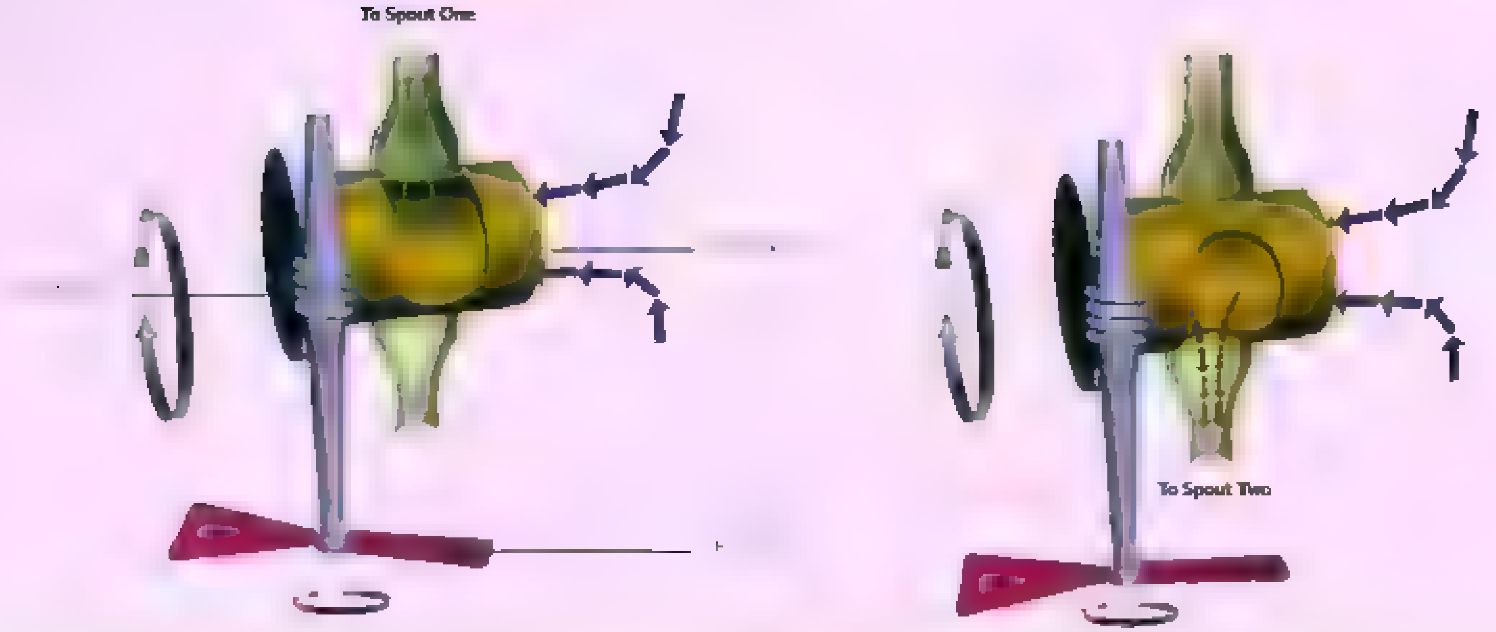
At the edge of this great fountain is a poem written by Ibn Zamrak. This praises the beauty of the fountain and the power of the lions but it also describes the ingenious hydraulic systems and how they actually worked, which baffled all those who saw them. To this day the system has remained exactly the same. It is just gravity and water pressure.

'... are there not in this garden wonders
that God has made incomparable in their beauty,
and a sculpture of pearls with transparent light,
the borders of which are trimmed with seed pearl?
Melted silver flows through the pearls,
to which it resembles in its pure dawn beauty.
Apparently, water and marble seem to be one,
without letting us know which of them is flowing.'

Part of the Lion Fountain poem by Ibn Zamrak

[illegible] Alhambra Palace [illegible] of the [illegible] Mountains [illegible] water for [illegible]

The Lion Fountain at the Alhambra, Spain is nearly a thousand years old. It is believed that the twelve lions formed a water clock. [illegible] such that the water emerged from the first lion indicated 1 o'clock and so on for each hour.



A modern description of the Banu Musa Brother's navel valve which they built for automating the changing shape of fountains. As the water turns the propeller, the worm and wheel turn the valve attached to the main water pipe, thus allowing water to flow onto one spout at a time. Each spout generates its own fountain shape, giving the impression of a self changing fountain.

The Banu Musa Brothers' Fountains

Muslim engineers spent a lot of time and effort inventing various ways of representing water and controlling the way it flowed, because water is connected with Paradise. Some of the most ingenious people to do this were the Banu Musa brothers in the early 9th century.

These brothers, Jafar Muhammad, Ahmed and al Hasan, wrote a *Book of Ingenious Devices*, which included fountains that continuously changed their shape. For the 9th century, and even today, these fountains produced a sense of mysticism and amazement because of their splendour and variety of watery shapes.

The brothers talked about six designs. The first ran through basic styles found in all fountains, and the other five discussed how the fountains could be used together to form more intricate, shape-changing fountains.

The Banu Musa brothers' fountain designs were full of fine technology, like worm gearing, valves, balance arms, and water and wind turbines. All this showed their competence as designers, and as craftsmen they had a great understanding of manufacturing techniques and fluid mechanics to be able to make devices like navel valves.

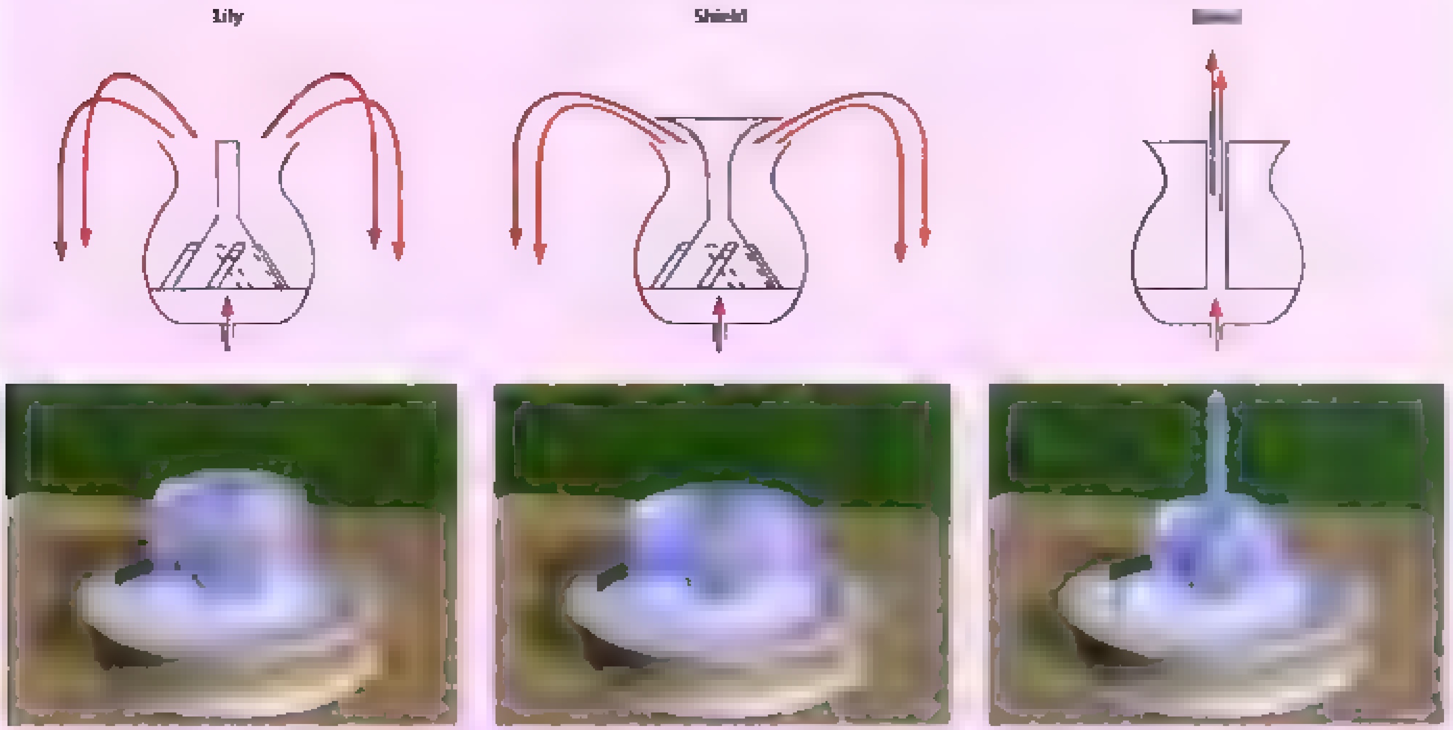
The most breathtaking fountains were those that could change shape, from say a spear to a shield and back again at certain intervals. They could do this because each had what was described as a bud where the water spurted out. It was this bud, and the pipes that led to it, that dictated which shape appeared. The three basic shapes were shield, spear and lily, and all three could emerge from the same fountain. But first a large vessel of water had to be placed high above the fountain and out of sight, to give it sufficient pressure to obtain the desired water shape.

Some fountains used worm gears and a clever hollow 'navel' valve, called so as it is shaped like a person's navel. It was this valve that directed where the water would go to produce which spouting shape.

The use of the worm and wheel to transmit motion from the flowing water to the revolving pipe was a major leap forward in the inventions of control systems engineering, which were essential for the invention of automatic machines during the industrial revolution.

Fountains today are carrying on this tradition of incorporating the latest fine technology, but now this involves light and music in time with jets of water. A millennium later and water, plus human ingenuity, is still amazing us.

The Three Basic Styles of Fountain by the Banu Musa Brothers



The balance was a pipe that carried the water from the main reservoir and had two positions, horizontal (red) and raised (green) in the figure. When horizontal, water went from the reservoir to the left tank which fed pipes that went through to the bud making a spear-shaped fountain. As this was happening, small containers attached to the arm of the balance slowly filled with water. These eventually tipped the balance arm to its raised position. When raised, water from the main reservoir was channelled into the tank on the right, feeding the shield shaped bud. The small containers on the side slowly emptied, until the balance returned to its horizontal position and the process repeated over and over as long as there was water in the main reservoir.

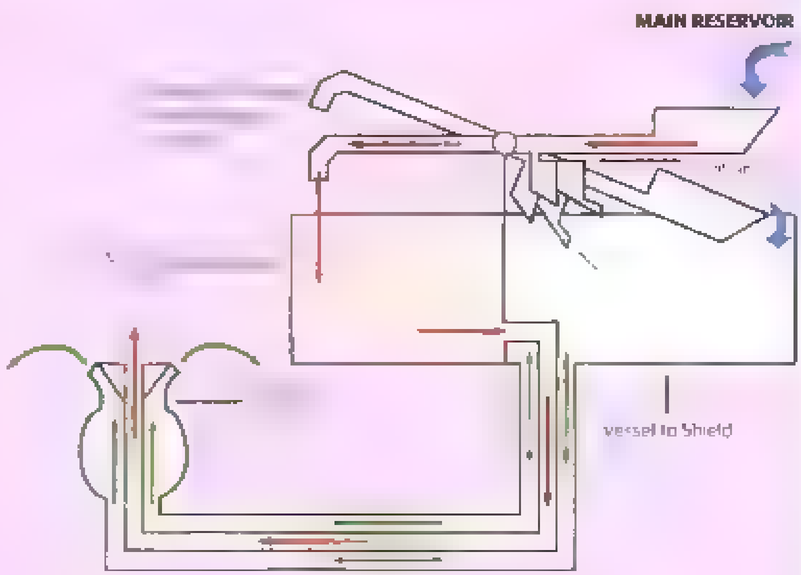
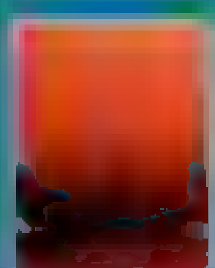
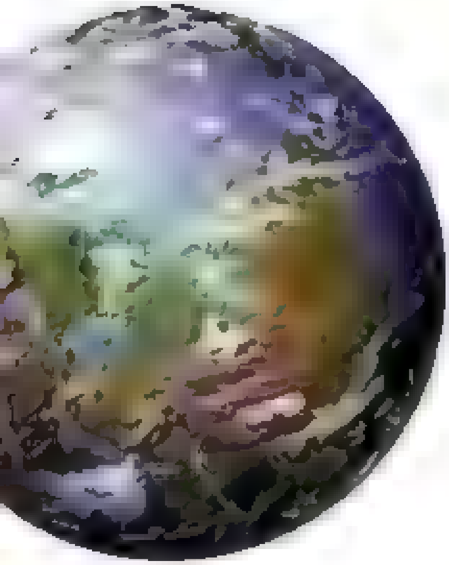


Illustration showing how the balance system worked for Banu Musa brothers fountain design.

06 WORLD

> 'The Earth is spherical despite what is popularly believed ... the proof is that the Sun is always vertical to a particular spot on Earth.'
>
> Ibn Hazm, a 10th-century man of letters from Cordoba, Spain





Planet Earth

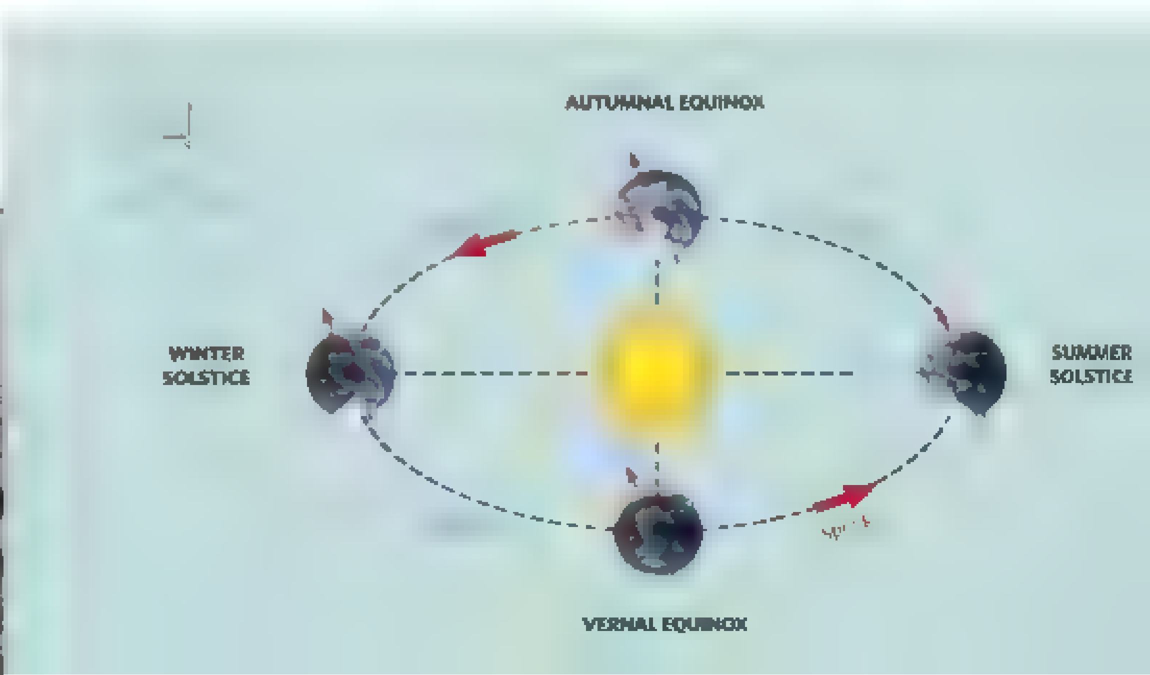
THERE WAS A TIME when the idea of the world as a tilting, wobbling, land and sea covered molten globe spinning on its own axis, while tracing an elliptical path around a fiery orb, would have been an absurd suggestion. Only through centuries of observation and experimentation by succeeding civilizations can we now be sure that this is really the case and it is called planet Earth.

Ptolemy in 127–151 CE was the one to begin the great debates. As a great astronomer and mathematician of antiquity, he estimated the change in longitude of the fixed stars to be about 1° per century, or 36 seconds annually when he described the then supposed Earth centred system of the universe. Today this movement is known as 'the precession of the equinoxes,' and is understood as the Earth slowly wobbling on its rotation axis through its orbit, caused by the gravitational pulls of the Sun and the Moon on the Earth's equatorial bulge.

What we also know today is that over a cyclical period of 25,787 years, this wobble influences the time at which the Earth is closest to and farthest from the Sun, and ultimately, it also affects the timing of the seasons. This also means the stars and constellations slowly drift westward.

Muslim astronomers obtained increasingly accurate figures about the precession of the equinoxes than Ptolemy had. The renowned 10th-century Baghdad astronomer, Muhammad al-Battani said it was 1° in sixty six years, or 54.55 seconds per annum, or 23,841 years for a complete rotation. Ibn Yunus, who died in 1009, said it was 1° in seventy years, or 51.43 seconds per annum, or a rotation in 25,[illegible]75 years. This compares amazingly well with the present-day figure of about 50.27 seconds per annum, or about 25,787 years for a complete rotation.

Left: [illegible] Claudius Ptolemy (2nd century CE) was one of the first astronomers to calculate the precession of the equinoxes; observing the seasons of the year led Muslim scholars to study and calculate the tilt of the earth.



It is the Earth's tilted axis to the plane of the elliptical orbit that is the main cause of the seasons, so, for example, when the northern hemisphere is tilting towards the Sun, we are in summer. As the Muslims discussed the phenomenon of seasons, they were also studying and calculating the tilt of the Earth.

Discovering the exact degree of tilt became a matter for intense deliberation amongst astronomers and mathematicians in the centuries following Ptolemy. In the late 10th century, a Tajikistan mathematician and astronomer named al-Khujandi built a huge observatory in Rayy, near Tehran, Iran, to observe a series of meridian transits of the Sun. These let him calculate, with a high degree of precision, the tilt of the Earth's axis relative to the Sun.

Today, we know this tilt is approximately 23°34', and al-Khujandi measured it as being 23°32'19", so he was pretty close. Using this information, he also compiled a list of latitudes and longitudes of major cities.

A century before this discovery, the enlightened 9th century Caliph, al-Ma'mun, engaged a group of Muslim astronomers to measure the Earth's circumference. They did it by measuring the length of the terrestrial degree, which they found to be 56,666 Arabian miles or 111,812 km, which brought the circumference to 40,253.4 km. Today we know the exact figure of the Earth's circumference is 40,068.0 km through the equator, and 40,000.6 km through the poles, so they weren't far out either.

Al-Biruni, an 11th-century polymath, said, with a touch of dry humour: 'Here is another method for the determination of the circumference of the Earth. It does not require walking in deserts.' He calculated the figure by using a highly complex geodesic equation and wrote it all up in his book *On the Determination of the Coordinates of Cities*. Len Berggren, a contemporary writer, says, 'It doubtless gladdened al-Biruni's heart to show that a simple mathematical argument combined with a measurement could do as well as two teams of surveyors tramping about in the desert.'

Al-Biruni's book also made a systematic and detailed study of the measurements of the Earth's surface. He measured latitudes and longitudes, and determined the antipodes and the roundness of the Earth. He was a man genuinely ahead of his time, and even discussed the theory of the Earth rotating about is own axis six hundred years before Galileo.

Many educated Muslims, including al-Biruni at this time took it for granted that the Earth was round. Ibn Hazm, a 10th century man of letters from Cordoba, said, 'the Earth is spherical despite what is popularly believed ... the proof is that the Sun is always vertical to a particular spot on Earth.' This is another example of where Muslims scientists were carrying out groundbreaking research that was based on observation and experimentation rather than hearsay and myth.

Surveying

SURVEYING IS THE MEASURING of angles and distances on the ground so that they can be accurately plotted on maps. It's used for laying out roads, buildings and land plots for construction, as well as when marking borders between properties and countries. The Romans had used simple surveying techniques to 'balance or equalize the land,' and these were taken on by Muslim and Christian Spain. They included a simple triangular level with a plumb line.

What the Romans didn't have was triangulation, which is a method used today in surveying. It was introduced from the East in the astrolabe treatises of two Muslim Spanish scholars, Maslama and Ibn al-Saffar, and Maslama's work was translated into Latin by John of Seville in the 12th century.

There are a variety of triangulation procedures that can be done with the astrolabe, including the measuring of height and distance by right-angled triangles and squares. Using this instrument, alongside Roman surveying procedures, meant that simple triangulation could be practised with an alidade (a rule with sights at either end) by Muslim surveyors.

A 10th century book called *Geometria* was a compilation of Spanish Muslim inspirations, and used by the Monastery of Ripoll in Spain. This gave details of a variety of triangulation procedures that could be used with an astrolabe, especially for producing straight boundaries to large areas of land.

There were even teams of surveyors to carry out the challenging projects (just like today), such as surveying irrigation canals. In al-Andalus, these teams were called *muhandis*, and in eastern Spain they were known as *soguejador*.

Today, triangulation is still used to determine the location of an unknown point by using the laws of plane trigonometry, but with the help of advanced technology, such as the Global Positioning System.

Right: The back of the astrolabe is engraved with a shadow square, which could be used for surveying purposes. This astrolabe was made in 1641/2 by Muhammad Muqim ibn Mulla Isa in Lahore, Pakistan. Modern surveying no longer depends on astrolabes.

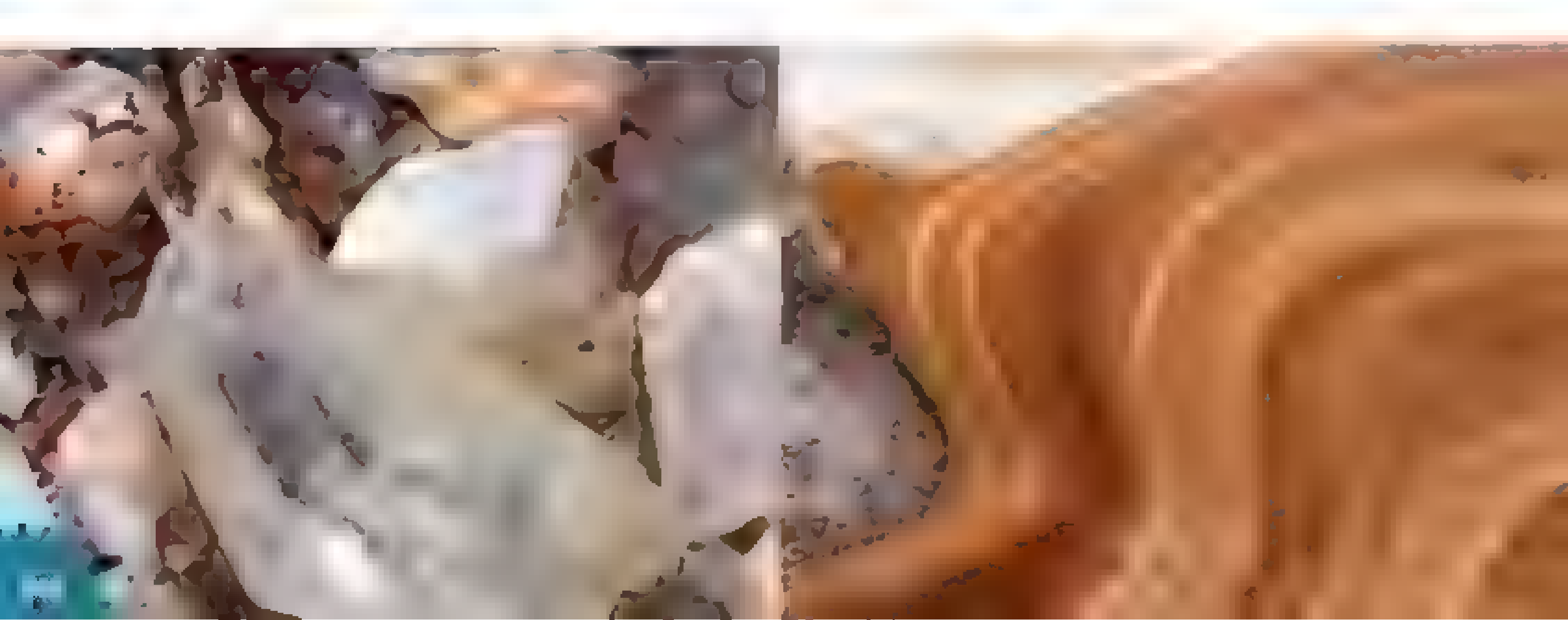
Earth Science

MINERALOGY IS THE SCIENCE of studying minerals, and today there is the International Mineralogical Association (IMA) which represents mineralogists in individual countries. The subject has come a long way since Muslim mineralogists began studying this area a thousand years ago. Today, over four thousand species of mineral have been recognized by the IMA.

A mineral is a naturally occurring substance that has a definite chemical composition and crystalline structure. In other words, a mineral is a crystalline, chemically pure, natural material. Things like gold, like diamond, quartz, calcite, sapphire and pearl are all examples of minerals.

Gems and precious stones are special types of minerals. They are rare, beautiful (in colour, transparency and lustre), and hard enough to resist physical and chemical changes for some time. Diamonds, rubies, sapphires and emeralds all have these properties. The importance of gems to emperors, kings and the wealthy has possibly been the driving force behind their discovery since the dawn of human civilization.

The ancient Egyptians, Mesopotamians, Indians, Greeks and Romans knew of certain varieties of mineral, precious stones and gems. Most of the lands of these people became part of the Islamic State or Caliphate. Consequently, their writings on gems and minerals, like other subjects, were translated into Arabic in the first three hundred years of the Islamic world. So, it's not surprising to find the best contributions by Muslim scientists to mineralogy and gemmology occurring a hundred years after these translations, when the work of the ancients was absorbed and ready for the new Muslim scientists and explorers to carry on the work and research.



Meanwhile, the enormous area that the Islamic world covered meant that Muslims could study and develop earth sciences not only in the Mediterranean world, like the Greeks had done, but also in Europe, Asia and Africa. Knowledge of minerals, plants and animals was gathered from areas as far away as the Malay islands and brought together in books such as 11th century scholar Ibn Sina's *The Book of Cure*, which was essentially an encyclopaedia of philosophy and natural sciences. This became very famous and influenced European scientists during the Renaissance because of the valuable information it contained.

Ibn Sina, known as Avicenna in the West, was a true product of Muslim civilization at the height of its scientific growth, but he is better known today in medicine and philosophy than earth science. However, in his *Book of Cure* there is an important chapter on mineralogy and meteorology, where he presented a complete coverage of the knowledge of his day regarding what happens on the Earth. It was composed of six sections: on the formation of mountains, the advantages of mountains in the formation of clouds, sources of water, the origin of earthquakes, the formation of minerals, and the diversity of the earth's terrain. Many of these findings are now ascribed to James Hutton, who lived in the 18th century.

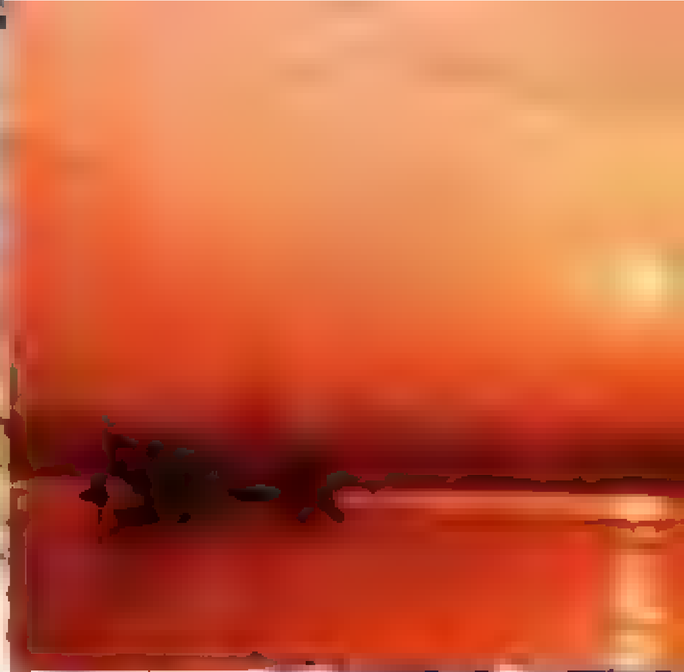
These fundamental principles of geology were put forward many centuries before the Renaissance in Europe, where earth science was first called geology. Historians have acknowledged Avicenna's contribution to the field of geology, and said that in the 11th century he was already suggesting a hypothesis about the origin of mountain ranges which, in the Christian world, would still have been considered quite radical eight hundred years later.

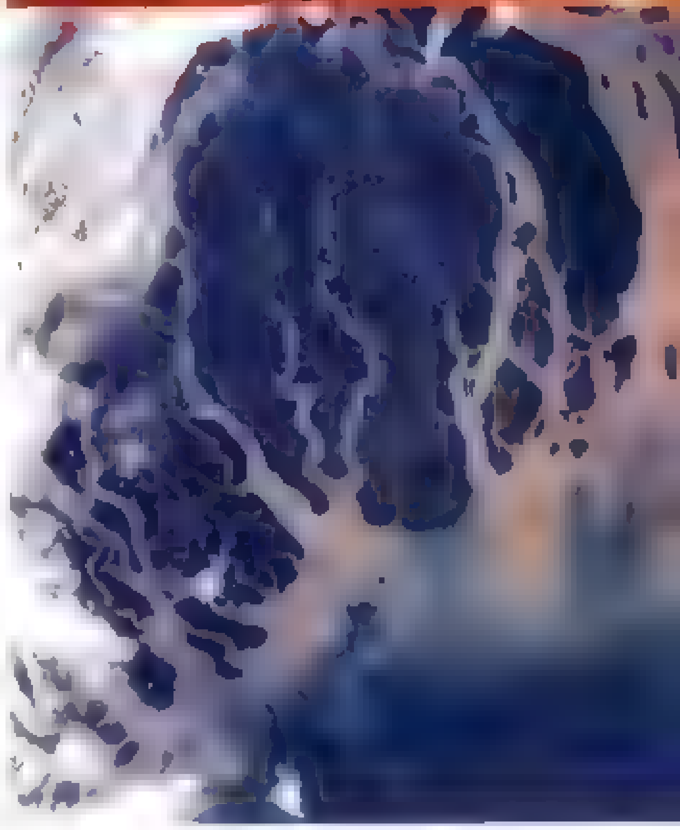
I bought some raw pebbles [illegible] brought from India. I heated some of them, they became more red ... there were two very dark pieces, one was with reddish colour, the other was less red. I put both pieces in a [illegible] and directed the flame at them for a period sufficient to m[illegible] [illegible] old. I took the pieces a[illegible] [illegible] less red [illegible] with a rose red [illegible] deep red piece [illegible] its colour and became like [illegible] (now Sri Lanka) [illegible] I then examined this latter piece [illegible] that it was softer than [illegible] ruby] ... I concluded when redness is lost with heating the heated material is not [illegible] This conclusion cannot be reversed, i.e. if the heated material stays red it is not necessarily yaghut, because iron stays red after heating.

11th century [illegible] scientist al-Biruni [illegible] ting rubies, from his book treatises on how to recognize gems

Ibn Sina's work on Earth science preceded that of James Hutton (1726-1797). Portrait by Abner Lowe.

Many of these findings are now ascribed to James Hutton who lived in the 18th century ... but ... the fundamental principles of geology were put forward many centuries before....





Right: Ganges river delta. Early 11th century scholar al-Biruni spent most of his time studying in India, where he correctly identified the sedimentary nature of the Ganges basin.

Ibn Sina's *Book of Cure* was known in Renaissance Europe through its Latin translation. It was a source of inspiration to the founders of geological thought in Europe, men such as 15th century Leonardo da Vinci, Steno in the 17th century and James Hutton in the 18th century.

Ibn Sina wasn't the only Muslim scholar pushing the boundaries of knowledge. Another big name in the field of earth science was al-Biruni, who was a contemporary of Ibn Sina.

Al-Biruni was born in what today is southeast Turkey in 973 CE. Like many of his contemporaries, one label alone cannot be assigned to him professionally because he wrote prolifically in many areas, including mathematics, astronomy, medicine, philosophy, history, pharmacy, and earth science or mineralogy.

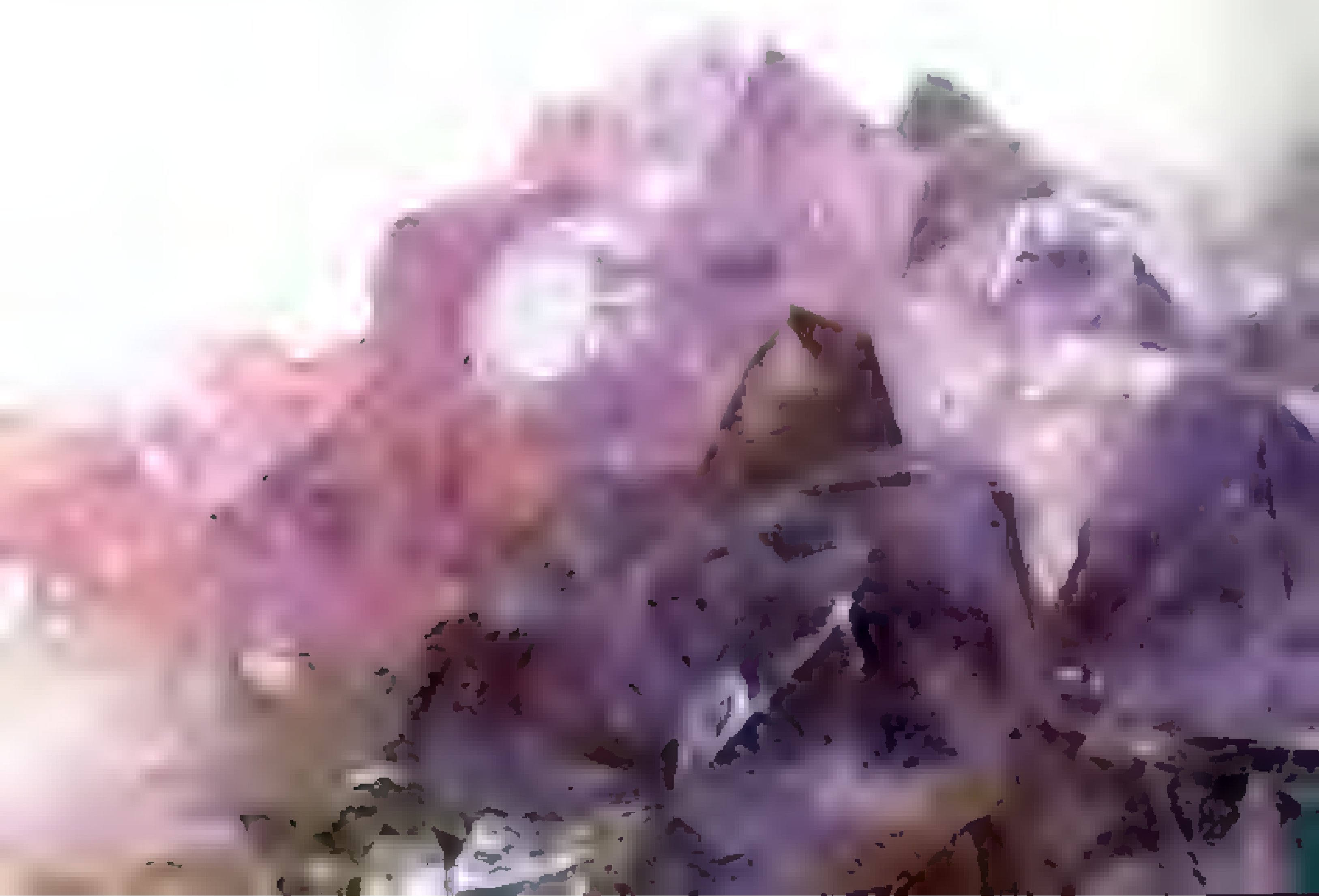
A great deal of his time was spent in India, where he learnt the language and studied the people, religion and places. This he wrote up in his vast book called *Chronicles of India*. As well as speaking Hindi he also knew Greek, Sanskrit and Syriac, although he wrote all his books in Persian and Arabic. His time in India meant he looked intensely at its natural history and geology, and he correctly described the sedimentary nature of the Ganges basin. His great mineralogical work was called *Treatises on How to Recognize Gems*, and it made him a leading scientist in this area.

Of course Ibn Sina and al-Biruni were not the only two to be producing important works on

mineralogy. Here are a few more with their achievements: Yahya ibn Masawayh (died 857), who wrote *Gems and Their Properties*; al-Kindi (died about 873), wrote three monographs, the best of which was *Gems and the Likes*, but which is now lost; al-Hamdani, a 10th-century scholar, wrote three books on Arabia in which he described methods of exploration for gold, silver and other minerals and gems, their properties and locations; and the 10th century group of scholars known as *Ikhwan al-Safa'* (the Brothers of Purity), wrote an encyclopaedic work that included a part on minerals, especially their classification.

Unfortunately, most of what was written on the subject of minerals, stones and gems has been lost, but a few works survived and are now in print.

Muslim civilization was outstanding in its natural outlook towards the universe, humanity and life. Muslim scientists thought and wondered about the origin of minerals, rocks, mountains, earthquakes and water. This is the nature of earth science itself, or what we now know as geology, and the history of geology reflects human thought upon the nature of our Earth.



Natural Phenomena

It is children who usually ask us the difficult questions like 'why is the sky blue?', 'where does the rainbow end?' and 'why does the sea lap at the sand?' Today we take many things from the natural world around us for granted, but Muslim minds of the 9th century were thinking deeply about these questions out of a curiosity to understand their surroundings, and Allah's creation motivated them.

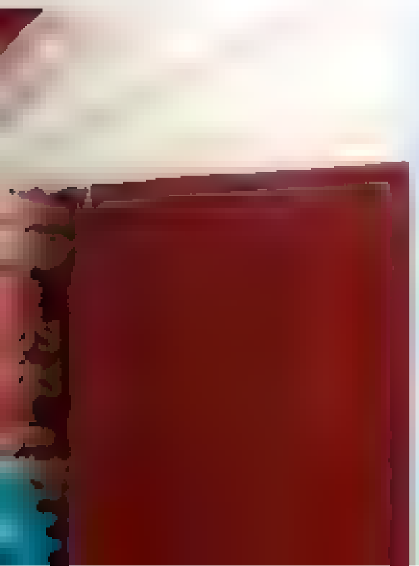
Before and at the time of Ibn Hazm, who was a 10th century man of letters from Cordoba, astrologers believed that stars and planets had souls and minds and that they influenced people. Ibn Hazm took a more pragmatic view and said that 'the stars are celestial bodies with no mind or soul. They neither know the future nor affect people. Their effect on people however can be through their physical characteristics, such as the effect of the Sun's heat and rays on the planets and the effect of the Moon on the tides of seas.'

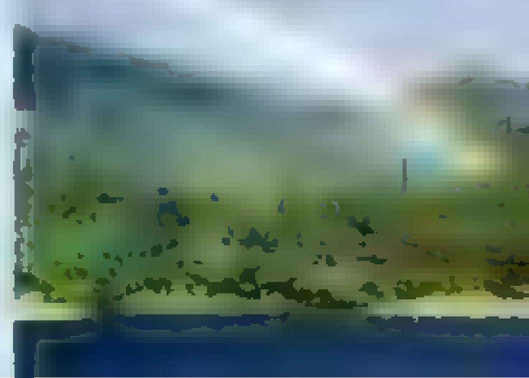
Another scholar of the 11th century, al-Biruni, explained that the increase and decrease in the height of the ebbs of tides occurred in cycles on the basis of changes in the phases of the Moon. He gave a very vivid description of the tide at Somnath, a city in India, and traced it to the Moon.

As they studied the heavens, some scholars, like al-Kindi, commented on the blueness of the sky. He did this in a short treatise with a long title: *Treatise on the azure colour which is seen in the air in the direction of the heavens and is thought to be the colour of the heavens*. More simply, he was telling people why the sky was blue. Al-Kindi said that it was due to the 'mixture of the darkness of the sky with the light of the atoms of dust and vapour in the air, illuminated by the light of the Sun.' His words, like the length of the title, explain it fully:

'The dark air above us is visible by there being mingled with it from the light of the Earth and the light of the stars a colour midway between darkness and light, which is the blue colour. It is evident then that this colour is not the colour of the sky, but merely something which supervenes upon our sight when light and

Below (middle to right): The gravitational pull of the Moon causes the rise and ebb of tides as described by al-Biruni in the early 11th century, at around the same time as al-Biruni, Ibn al-Haytham was describing the phenomenon of rainbows.





Ibn al-Haitham also studi
and explained the halo eff
and the visual effect of wh
the Moon appears larger
than it is. Kamal al-Din
al-Farisi later carried on I
al-Haitham's work in the
splitting of white light

darkness encounter it. This is just like what supervenes upon our sight when we look from behind a transparent coloured terrestrial body at bright objects, as in the sunrise, for we see them with their own colours mingled with the colours of the transparent object, as we find when we look from behind a piece of glass, for we see what is beyond of a colour between that of the glass and that of the object regarded.

Al-Kindi was on the right lines, for the sky isn't really blue, in spite of the confused and impossible views which passed for knowledge, even in highly educated circles, in his time. He could compete with these views because he was a widely read man and excelled in science, mathematics and music and was a physician in 9th-century Baghdad.

Ibn al-Haitham also went against the conventional wisdom of his day. It was a thousand years ago in Cairo that he was placed under house arrest because he couldn't regulate the flow of the Nile as the caliph had asked him too. He knew that if the Ancient Egyptians hadn't been able to do it, then neither would he. To save his skin and continue his studies, he pretended to be mad. The house arrest suited him because it meant that he could concentrate all his time on observing the rays of light that came through holes in his window shutters.

The time he had for observation and experimentation meant he could explain phenomena like rainbows, halo effects, and why the Sun and Moon seem to grow in size when they are near the horizon. He said it was the effect of the atmosphere that increased the apparent size of Sun or Moon as they neared the horizon, adding that the increased size was a visual trick played by the brain. He showed that it was through atmospheric refraction that the light of the Sun reaches us, even when the Sun is as many as nineteen degrees below the horizon, and on this basis he calculated the height of the atmosphere at ten miles.

Kamal al-Din al-Farisi, who died in 1319, repeated and improved on Ibn al-Haitham's work by observing the path of the rays in the interior of a glass sphere. He hoped to determine the refraction of solar light through raindrops, and his findings enabled him to explain the formation of primary and secondary rainbows, which is essentially the splitting up of white light by a prism.

So next time a child asks you 'why...?', maybe telling them about the work of these medieval Muslims would be a good starting point, which would lead them on their own journey of discovery.

Geography

ACCORDING TO THE WORLD RENOWNED MAGAZINE *National Geographic*, geography is 'the science of space and place that brings together Earth's physical and human dimensions in the integrated study of people, places, and environments.' In schools today we study the course of a river in one lesson and the tribes of Kenya in the next, to learn about and understand the fantastic places and people that surround us.

Muslims have always been outward looking, observing and recording their surroundings near and far. They were great travellers, explorers and merchants, and this practical awareness of the world inspired scholars to make great studies of places and people.

Their interest in geography was partly due to the environment in which they lived. They had to move, along with their precious flocks and herds, in search of fresh and better pastures, so knowledge of their surroundings including that of plants and wild animals, was vital. In these circumstances, the science of geography developed as a practical necessity.

The holy pilgrimage or the *hajj* was also a valuable source of material. Many pilgrims used word of mouth accounts of routes to Mecca and Medina, as they came from distant regions. These were later put in written form so travel guides passed on to others, helping them on the long and difficult journey of their holy pilgrimage from all corners of the empire.

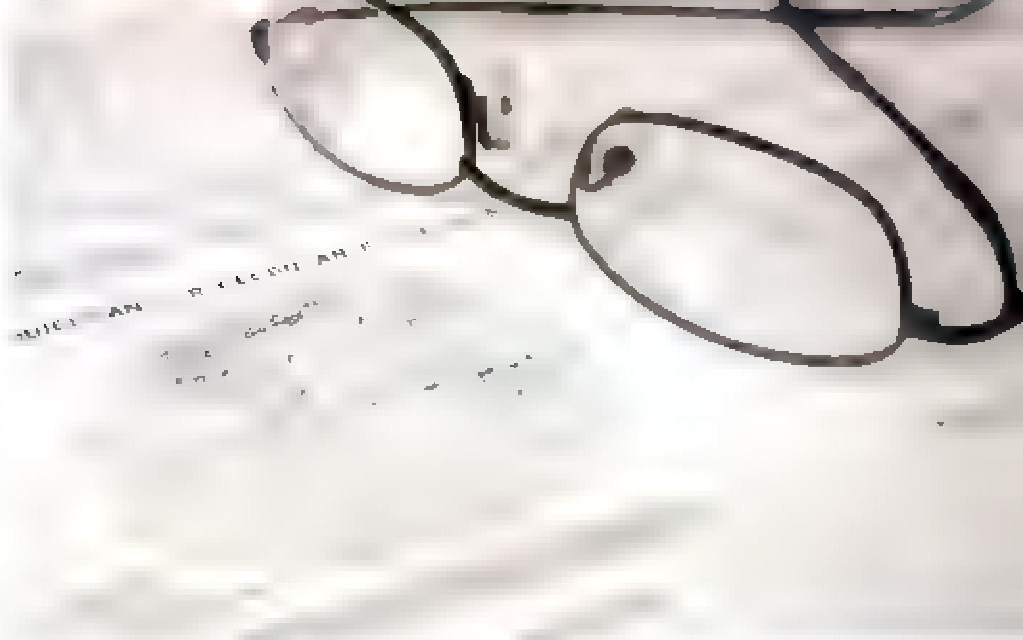
Then the orientation of the mosques towards Mecca was another impetus to study geography, as was the need to know the direction of the Ka'bah in Mecca for daily prayers. Finally wars and invasion and the political and administrative requirements of the expanding Muslim world, created another dimension in the search for geographical knowledge.

With the development of more accurate astronomy and mathematics, giant steps were made in the progress of geographical study, as map plotting became one of its respected branches. Al-Khwarizmi, a 9th-century Persian scholar, was one of the earliest scientific descriptive geographers, and a highly talented mathematician. His famous book, *The Form of the Earth*, inspired a generation of writers in Baghdad and Muslim Spain or al-Andalus, to unearth, analyse and record geographical data.

Another geographer named Suhrab, at the beginning of the 10th century, wrote a book describing various seas, islands, lakes mountains and rivers of the world. His notes on the Euphrates, Tigris and Nile are very significant, while his account of the canals of Baghdad is the main basis for the reconstruction of the medieval plan of that city. This reconstruction was done in 1895 by Guy Le Strange, who incorrectly read Suhrabs name as that of a well known physician named Ibn Sarabiyun (or in Latin, Ibn Serapion). Le Strange also used work by al-Ya'qubi, who was from the 9th century, in his reconstruction. The two texts, Suhrab's account of the water system network and al-Ya'qubi's description of the highways coming from Baghdad, complemented each other very well.

Al-Muqaddasi was a 10th-century Muslim geographer. He travelled throughout the Muslim world, observing, corroborating, weighing and sifting evidence, taking notes and writing. The outcome of years of travel was *Best Divisions for Knowledge of the Regions*, completed in 985. It appealed to a variety of people while also being an entertaining read. Like many before and after him, his reasons for scholarly research were divine inspiration. What he produced would be a way of getting to know God better and he would also receive just reward for his endeavour. His great book created the systematic foundation of Muslim geography, as he introduced geographic terminology, the various methods of division of the earth and the value of empirical observation.

One of the earliest Turkish geographers was Mahmud al-Kashghari, who was also a well known lexicographer. He drew a world map which looked unusual and circular, on a linguistic basis. It appears in his masterpiece work, a treatise on grammar called *Compendium of Turkish Dialects*, completed



in 1073. A considerable portion of Central Asia as well as China and North Africa were also included, but little beyond the Volga in the West. This is perhaps because it was drawn before the Turks began to move west.

In the 11th and 12th centuries, two Muslim writers, al-Bakri and Ibn Jubayr, collected and collated the information assembled by their predecessors into an easily digestible format. The first of them was the son of the Governor of the province of Huelva and Saltes in Spain. Al-Bakri himself was an important minister at the court of Seville who undertook several diplomatic missions. Despite his busy official duties, he was an accomplished scholar and essayist. He wrote

A stamp, issued in 1962 showing a map of old Baghdad (surrounded by a circular wall) as described by Al-Ya'qubi (9th century) and the water system network as recounted by Suhrab (10th century).

Al-Muqaddasi was a 10th-century Muslim geographer and produced his book of his travels.

An artistic impression showing al Idrisi in the court of Roger II of Sicily with a silver globe that he created to show that the Earth was spherical

an important geographical work devoted to the Arabian Peninsula, including the names of various places. *The Hadith and Histories* was alphabetically arranged, including the names of villages, towns, valleys and monuments. His other major work was an encyclopaedic treatment of the entire world

Ibn Jubayr of Valencia, who was secretary to the Governor of Granada, Spain, was one of those who habitually recorded his *hajj* journeys to Mecca. These seven-hundred-year-old travel books were journals, giving a detailed account of the eastern Mediterranean world. His itineraries and road books all went well beyond the branch of geography to include botany, culinary information and travel advice

In Muslim Spain, the passion for keeping travelogues thrived, and this inspired the compilation of the most comprehensive world atlas of the time, by the highly celebrated scholar al Idrisi. He was commissioned by the Norman king of Sicily, Roger II, in 1139 to come from Cordoba to Sicily and make a map for the king. He spent fifteen years on this, enjoying exalted status at the king's Palermo court, interviewing thousands of travellers and producing seventy accurate maps, including some territories previously uncharted

Reporter Rageh Omar presenting the BBC's *An Islamic History of Europe* says al Idrisi's work, called *A Recreation for the Person who Longs to Traverse the Horizons*, is 'widely recognized as being the greatest single work of geography in the medieval era.' The *Book of Roger*, as it was also known, was an atlas and showed that the earth was round. Al Idrisi even made a silver globe to stress the point

Al Idrisi was a European Muslim living in a Christian country, outside the Muslim Caliphate, and was fully accepted, greatly adding value to this society. He depicted the entire continents of Europe and Asia and Africa north of the equator, two centuries before Marco Polo.

This is the Idrisi map of the world drawn for King Roger II. Note the Arabic is [illegible] because people in those days looked at South [illegible] map of the world [illegible] 12th century [illegible] Africa, Asia, the Mediterranean [illegible]

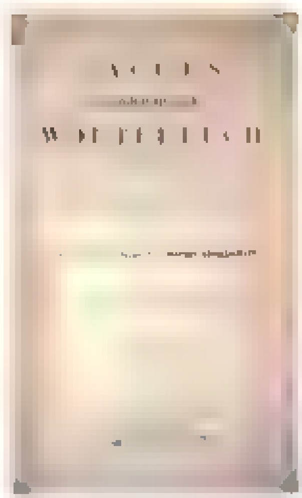
> *Arab scientists had long known this [that the earth was round] but Europeans still clung to the belief that it was flat.... He [al-Idrisi] also included a travel guide and map, surprisingly accurate for three hundred and fifty years before Columbus. It described England as 'gripped in perpetual winter.' It is an essential ingredient in this Islamic scholarship that helped shape European civilization.*
>
> *Rageh Omar in the BBC's* An Islamic History of Europe *on 12th century geographer al-Idrisi*

His work was based on that done by previous authors as well as on information he gathered in Sicily. Sicily was the place to be at this time, because it was the great crossroads of the Mediterranean and a melting pot of global trends, ideas and information.

As well as reiterating the fact that the earth was a globe, he calculated it was 22,900 miles in circumference, which isn't bad given that it is actually 24,902 at the equator. He also said that the earth remained stable in space like the yolk of an egg, while giving accounts of the hemispheres, climates, seas and gulfs. His work specifically contained a mine of excellent information about the remoter parts of Asia and Africa.

In the 13th century, Yaqut al-Hamawi toured from Mosul in Iraq to Aleppo in Syria, and then Palestine, Egypt, and Persia. Only four of his works have survived until today. The best known is his *Dictionary of Countries*. It's a vast geographical encyclopaedia, which summed up nearly all medieval knowledge of the globe including archaeology, ethnography, history, anthropology, natural sciences and geography, and gave coordinates for every place. He described and named every town and city, giving details of their every monument and their economy, history, population and leading figures.

Like many areas of science, technology and art, the list of personalities dedicated to the study of geography is immense. Many of them struck out into the world to gather information first hand, to quench a thirst for knowledge and understanding, to sate their curiosity, and to leave information that would help others. Today we have glossy magazines and TV satellite channels to experience our world. We learn and understand through professionals from our armchairs, unlike those from the last millennium who were guided by curiosity and faith to make sense of their surroundings.



13th-century traveller Yaqut al-Hamawi's *Dictionary of Countries* is still widely read; this is a 20th-century German translation

Maps

MAPS HAVE BEEN HELPING PEOPLE find their way for about three and half thousand years, with these earliest ones being on clay tablets. The introduction of paper was a leap forward in map making but the most recent cartographical revolution was with the development of Geographic Information Systems, or GIS. This meant that in 1973 the first computerized, large scale, digitized maps appeared in the UK, and by 1995, the whole country was completely digitized.

Before this modern technology, which uses a system of satellites and receiving devices to compute positions on the earth, maps were being made from travellers' and pilgrims' accounts.

The bug of travelling bit 7th-century Muslims, and they began to leave their homes for trade and religious reasons, to explore the world they lived in. They walked routes, sometimes simply gathering knowledge about new places, and when they returned gave accounts of the ways they had trodden and the people and sights they had encountered. First this was by word of mouth, but with the introduction of paper in 8th-century Baghdad, the first maps and travel guides could be produced.

With the introduction of paper, 8th-century Hajj pilgrims could produce maps to guide others to Mecca.

Reports were commissioned by the Abbasid caliphs to help their postmasters deliver messages to addresses within their empire. These accounts made up the *Book of Routes*, and this encouraged more intensive information gathering about faraway places and foreign lands, including their physical landscapes, production capabilities and commercial activities.

While Muslims were exploring the world, few Europeans were travelling such distances and the average European's knowledge of the world around them was limited to their local area, with maps usually produced by religious authorities. The great European explorers of the 15th and 16th centuries would probably not have set off, were it not for the geographers and map makers of the Islamic world.

The maps we have today are in the style of European maps, but they are only a few centuries old. The 'North' that is conventionally at the 'top' of a map is artificial, because European navigators started using the North Star and the magnetic compass for navigation. Before that, the top of the map on European maps was to the East, which is where the word orientation comes from. In medieval Europe, Jerusalem was usually placed at the top or in the centre, because that was the Holy Land.

A big difference between Islamic maps and European ones was that Muslims drew them with the south facing upwards and north downwards. With Muslim development of more accurate astronomy and mathematics, map plotting became a respected branch of science, and as far as Muslims were concerned the maps western cartographers drew later on were upside down, with the north facing upwards and south downwards.

In 1929, scholars working in Turkey's Topkapi Palace Museum discovered a section of an early 16th century Turkish world map signed by a Turkish captain named Piri ibn Haji Muhammad 'Re'is' (meaning Admiral), dated Muharram 919 AH or 1513 CE. This map has become the famous 'Map of America', and was made only twenty-one years after Columbus reached the New World.

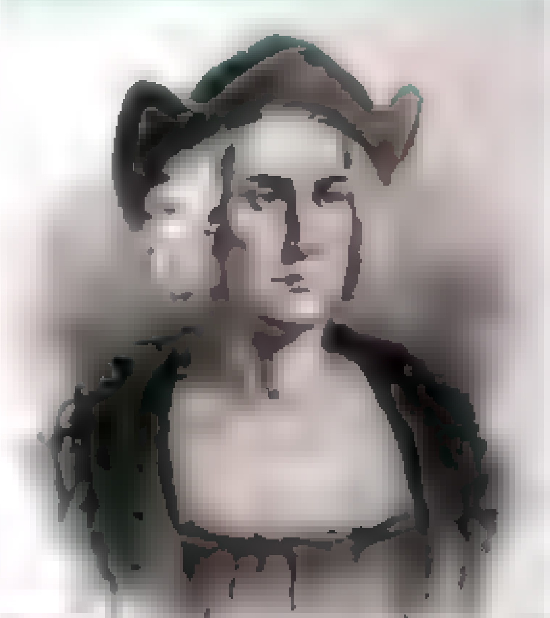
When the map was discovered, there was great excitement worldwide because of its connection with a now lost map made by Columbus during his third voyage to the New World and sent to Spain in 1498. In an inscription to the area of Brazil, Piri Re'is says: 'This section explains how the present map was composed. No one has ever possessed such a map. This poor man [himself] constructed it with his own hands, using twenty regional maps and some world maps, the latter including … one Arab map of India, four maps recently made by the Portuguese that show Pakistan, India, and China drawn by means of mathematical projection, as well as a map of the Western Parts drawn by Columbus…. The coasts and islands [of the New World] on this map are taken from Columbus's map.' No other traces of the maps made by Columbus have been found.

Very recently, a world map by the Muslim Chinese admiral Zheng He was discovered. It dates back to 1418. We are not sure yet whether Piri Re'is had come across it.

Charles Hapgood, in 1966, suggested that the Piri Re'is map shows Antarctica (307 years before it was 'discovered'). Now though, this theory has been thoroughly discredited, and it seems more likely that

'Columbus studied Arabic maps, without Jewish or Muslim expertise, Spain would not have become the greatest colonial power in 16th century Europe'

Rageh Omar presenting the BBC's An Islamic History of Europe



Left: Christopher Columbus, 1492

Below left: A replica of Christopher Columbus's flagship, the Santa Maria

Map by Piri Re'is, a Turkish admiral, from his 16th century book, *Kitab-ı bahriye*, showing Cyprus

it is the South American coastline, which has been bent to conform to the animal skin parchment on which the map was drawn. Also shown on the map are the Andes Mountains of South America, which were again 'first seen' by Spaniards in 1527, fourteen years after the map's production. This fragment of the 1513 world map showed adjacent coasts of Spain, the western coast of Africa and the 'New World', and was drawn on a gazelle skin. Piri Re'is has left a legacy of mystery, as he could not have acquired his information on Antarctica from contemporary explorers.

Piri Re'is didn't stop there, but made a second world map in 1528, of which about one sixth has survived. This covers the northwestern part of the Atlantic, and the New World from Venezuela to Newfoundland, as well as the southern tip of Greenland. Historians have been amazed by the richness of the map, and regret that only a fragment of the first world map was found. The search for the other parts has remained fruitless.

So who was this Piri Re'is, and why is his contribution to map-making absent from so many history books?

Piri Re'is was born towards 1465 in Gallipoli, and he began his maritime life under the command of his illustrious uncle, Kemal Re'is toward the end of the 15th century. He fought many naval battles alongside his uncle, and was later a naval commander, leading the Ottoman fleet that fought the Portuguese in the Red Sea and Indian Ocean.

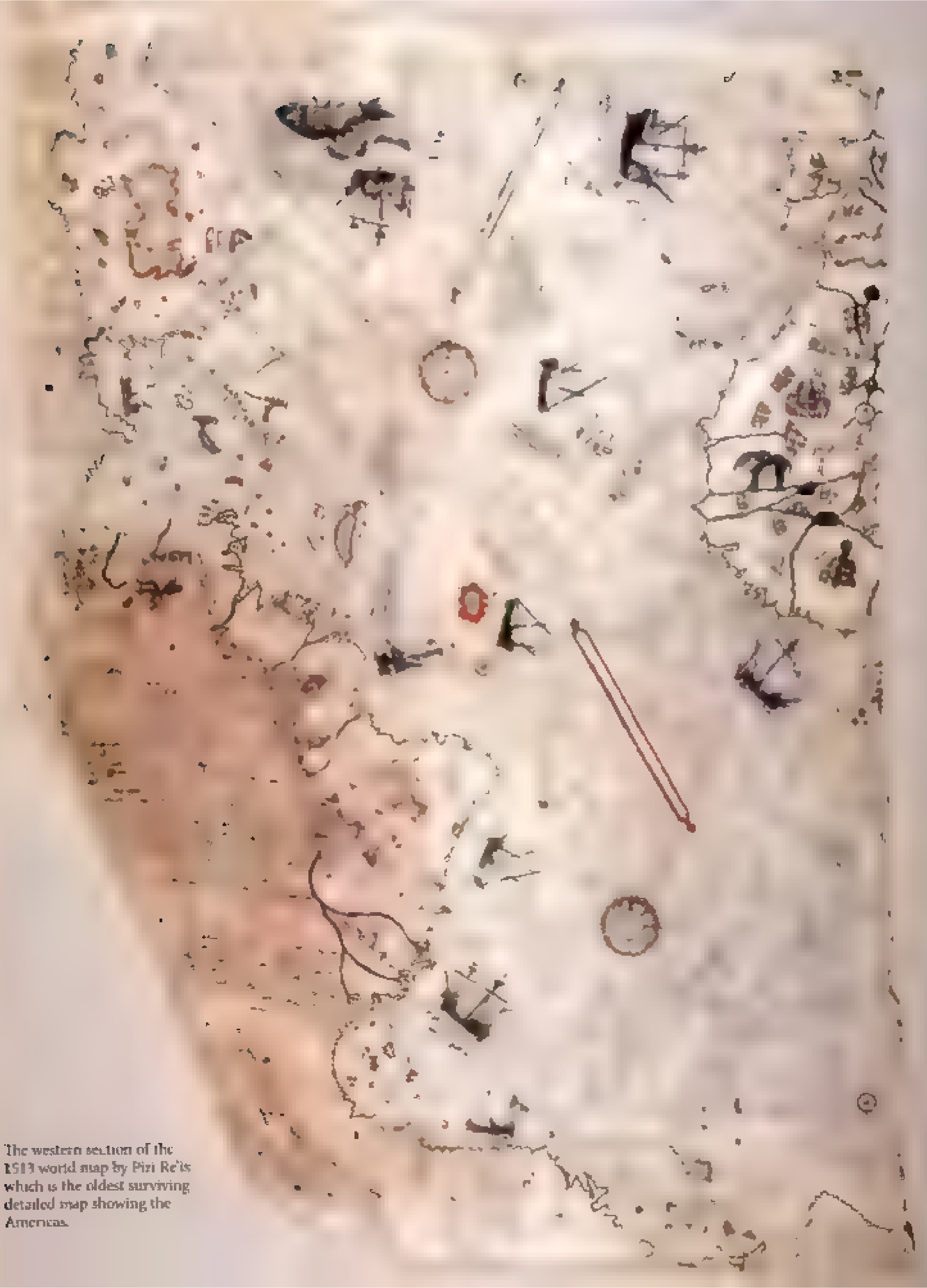
In between his wars, he retired to Gallipoli to devise his first world map, his *The Book of Sea Lore* (a manual of sailing directions), and a second world map in 1528. Mystery surrounds his long silence from between 1528, when he made the second of the two maps, and his reappearance in the mid-16th century as a captain of the Ottoman fleet in the Red Sea and the Indian Ocean. A sad end came to Piri Re'is, as he was executed by the Ottoman sultan for losing a critical naval battle.

Like a lot of the information in this book about 1001 inventions, not much of it has reached us, because Europe has concentrated on its own history, unravelling its own dramatic stories of oceanic voyages, discoveries, and commercial and colonial empires. Turkish maps were given little attention, or wrongly called Italian.

But in actual fact, Turkish nautical science was way ahead of its time. With Piri Re'is presenting his New World map to the Ottoman sultan in 1517, the Turks had an accurate description of the Americas and the circumnavigation of Africa well before many European rulers.

Perhaps the most staggering map of the world is that of Ali Macar, made in 1567, which depicts the world in such fine detail that it resembles modern-day maps and we can almost wonder if Ali Macar was looking at the earth from the moon.

Other important maps include seventy regional maps that al-Idrisi made for the Norman king, Roger II, in Sicily, which together made up a map of the world as it was then known. He interviewed thousands of travellers, producing accurate maps charting previously undocumented territories. For three centuries, geographers copied his maps without alteration. More can be read about this fascinating man in the 'Navigation' section of this chapter.



The western section of the 1513 world map by Piri Re'is which is the oldest surviving detailed map showing the Americas.

Travellers and Explorers

IN THE EARLY 1300S, Dar al-Islam, the Muslim world, was one of the greatest lands, stretching over much of the globe, bound together by the principles of Islam. Al-Biruni, a Turkish 11th century polymath wrote, in his *The Book of the Demarcation of the Limits of the Areas* that 'Islam, has already penetrated from the Eastern countries of the earth to the Western. It spreads westwards to Spain (Andalus), eastward to the borderland of China and to the middle of India, southward to Abyssinia and the countries of Zanj (Zanj meaning Black Africa from Mali to Kilwa [Tanzania] and Mauritania to Ghana), westward to the Malay Archipelago and Java, and northward to the countries of the Turks and Slavs. Thus the different people are brought together in mutual understanding, which only God's own art can bring to pass...'

'And He (Allah) has set up on the earth mountains standing firm, lest it should shake with you; and rivers and roads; that ye may guide yourselves; And marks and sign-posts; and by the stars (Men) guide themselves.'

Quran, (16:15&16)

The arteries that coursed through this great body giving it life were trading and pilgrim routes. Within this intermeshing system individual Muslim sultans ruled, and although there were military campaigns between them after the 13th century an everyday Muslim could pass through, albeit sometimes only with passports.

Ibn Battuta says when going into Syria: 'No one may pass this place ... without a passport from Egypt ... as a measure of protection for a person's property and a measure of precaution against spies from Iraq (a Mongol-conquered country) ... This road is under the Bedouins. At nightfall they smooth down the sand so that no mark is left on it, then the governor comes in the morning and examines the sand. If he finds any trace on it he requires the Arabs to fetch the person who made it, and they set out in pursuit of him and never fail to catch him.

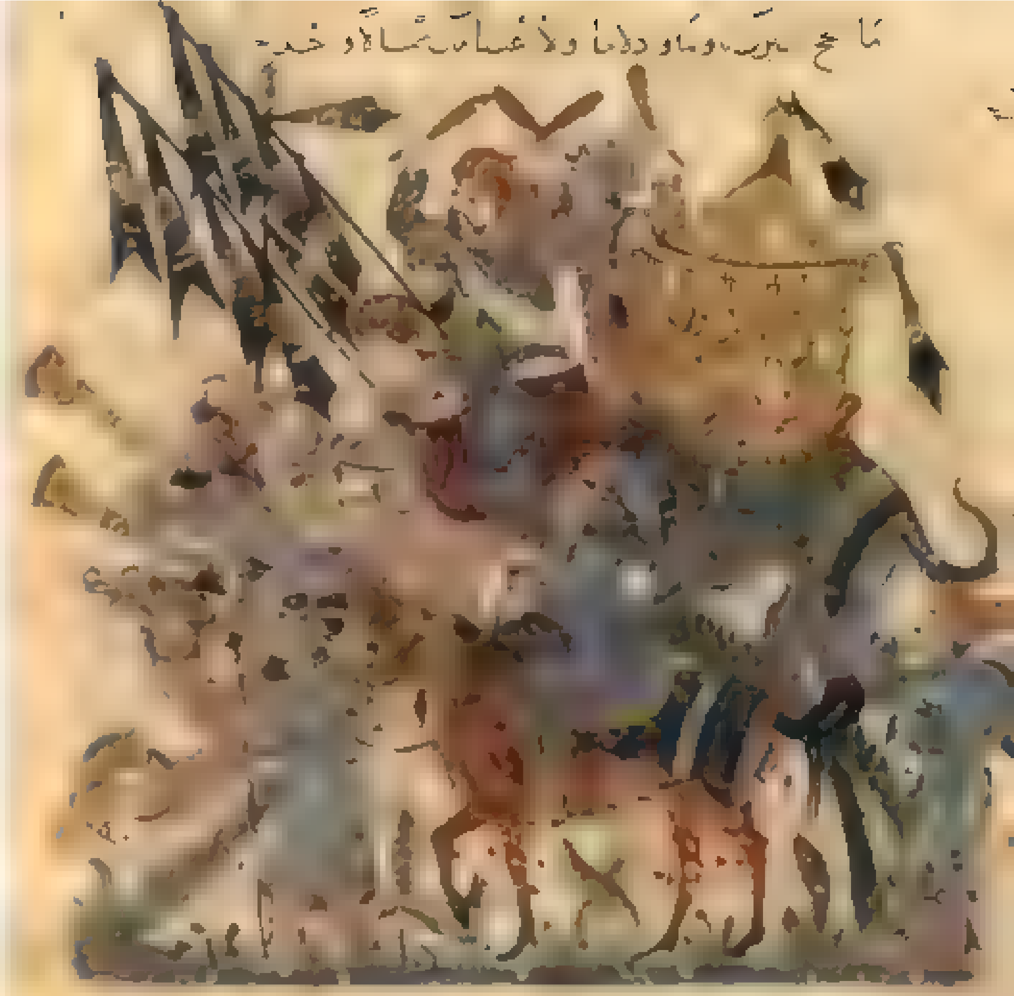
Top to bottom: 13th century manuscript showing a caravan going to Mecca; a camel caravan crossing the desert

The Muslims were natural explorers, since the Quran said every able-bodied person should make a pilgrimage, or *hajj*, to Mecca at least once in their lifetime. Thousands travelled from the farthest reaches of the Islamic empire to Mecca since the 7th century, even though transport was on foot, with only the lucky ones riding in tents on camels, on ox-driven carriages, or astride horses and donkeys. As they travelled, they made descriptions of lands and countries they passed through. Some of these were the first accounts of many places, including China.

The first descriptions of China were from the early 9th century, when trade with the Chinese was recorded in the Persian Gulf. Abu Zayd Hasan was a Muslim from Siraf, and said that boats were sailing for China from Basra in Iraq and Siraf on the Persian Gulf. Chinese boats, much larger than Muslim boats, also visited Siraf, where they loaded merchandise bought from Basra.

These boats sailed then along the Arabian coast, to Muscat, then Oman, and from there to India. All along the way, trade and exchanges were made, until the boats reached China and the town of Khanfu, now Canton, where an important Muslim colony grew. Here, Muslim traders had their own establishments, and exchanges took place involving the emperor's officials, who chose what suited him before any other person. From Khanfu, some Muslim traders travelled as far as the empire's capital, Khomda, which was a two-month journey.

Ibn Wahhab was a 9th-century trader from Basra who sailed to China and said that the Chinese capital was divided into two halves, separated by a long, wide road. On one side the emperor, his entourage and administration resided, and on the other lived the people and merchants. Early in the day, officials and servants from the emperor's side entered the other, bought goods, left and did not mingle again.



13th-century illustration of an eastern Muslim boat from the *Maqamat* or *Assemblies* of al-Hariri, where the Arabic writing refers to a sea voyage, and mentions a verse from the Quran referring to Noah's ark. This is normally used as a blessing: 'In the name of Allah, the one who protects the ship's sailing, seafaring and berthing.'

China, according to Muslim merchants, was a safe country, and well administered, with laws concerning travellers securing both good surveillance and security. Ibn Battuta says that 'China is the safest and best country for the traveller. A man may travel for nine months alone with great wealth and have nothing to fear.'

Al-Muqaddasi was a geographer who set off from his home in Jerusalem many centuries before Ibn Battuta. He also visited nearly every part of the Muslim world and wrote a book called *Best Divisions for Knowledge of the Regions*, completed around 985.

There were many other travellers who trod the world of Islam and farther. Al-Ya'qubi wrote a *Book of Countries* that he completed in 891, after a long time spent travelling, and he gave the names of towns and countries, their people, rulers, distances between towns and cities, taxes, topography and water resources. Ibn Khurradadhbih, who died in 912, wrote the *Book of Roads and Provinces*, which gave a description of the main trade routes of the Muslim world, referring to China, Korea and Japan, and describing the southern Asiatic coast as far as the Brahmaputra River, the Andaman Islands, Malaya and Java. 13th-century geographer Yaqut al-Hamawi wrote the encyclopaedic *Dictionary of Countries* about every country, region, town and city that he visited, all in alphabetical order, giving their exact location, and even describing a town's monuments and wealth, history, population, and leading figures. Abu al-Fida' wrote *The Survey of Countries* in the 13th century, and this had a huge reputation in the Latin West, so that by 1650 extracts about Khwarazm and Transoxonia were published in London.

Muslim travellers and the works they left have not been completely ignored by the West, as Gabriel Ferrand compiled, in the early 20th century, a great study of accounts by Muslim travellers of the Far East between the 7th and 18th centuries. This contained thirty-nine texts, thirty-three were Arabic, five were Persian, and one was Turkish. One of the early travellers to be covered is 9th-century al-Ya'qubi, who said that 'China is an immense country that can be reached by crossing seven seas; each of these with its own colour, wind, fish, and breeze, which could not be found in another, the seventh of such, the Sea of Cankhay only sailable by a southern wind.'

Travellers from the 9th to 10th century include Ibn al-Faqih who compares the customs, food diets, codes of dress, rituals, and also

It's reported that Prophet Mohammad (pbuh) had said 'seek knowledge even from as far as China.'

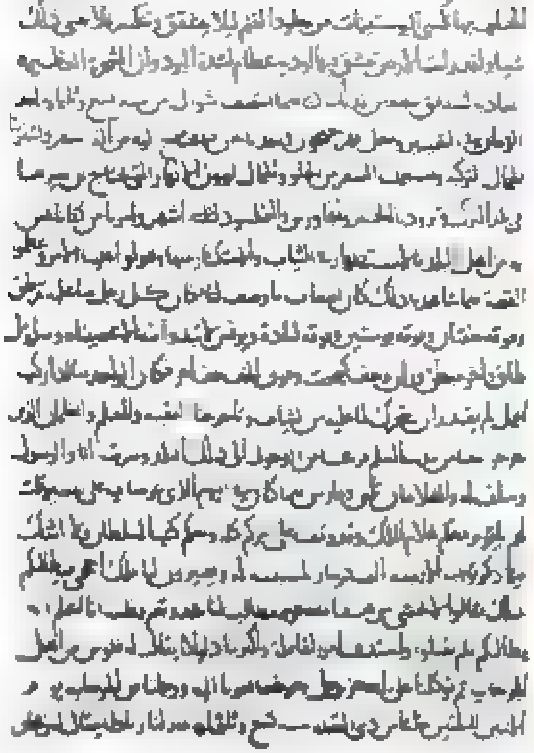
the flora and fauna of China and India, Ibn Rustah focuses on a Khmer king, surrounded by eighty judges, and his ferocious treatment of his subjects while indulging in drinking alcohol and wine, and also his kind and generous treatment of the Muslims; Abu Zayd also deals with the Khmer land and its vast population, a land in which indecency, he notes, is absent. Abu al-Faraj dwells on India and its people, customs, and religious observations. He also talks of China, saying it has three hundred cities, and that whoever travels in China has to register his name, the date of his journey, his genealogy, his description, age, what he carries with himself, and his following. Such a register is kept until the journey is safely completed. The reasoning behind this was a fear that something might harm the traveller and bring shame to the ruler.

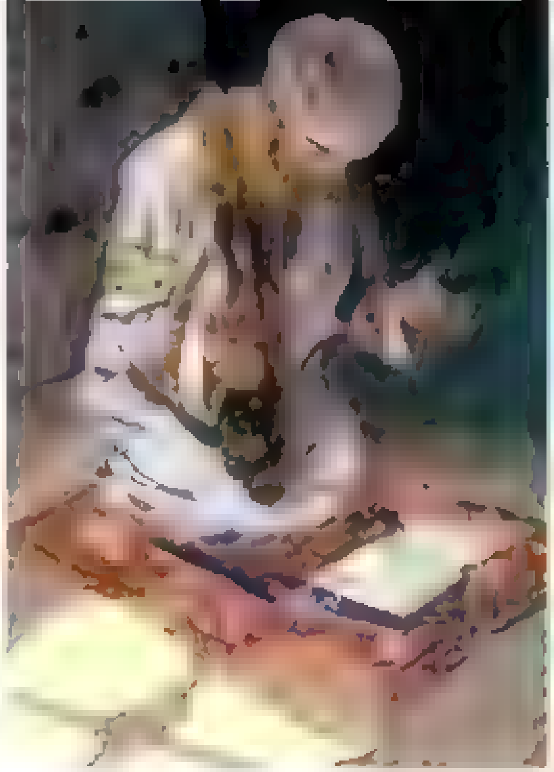
Ferrand also referred to 13th-century travellers like Zakariya' ibn Muhammad al-Qazwini, who has left accounts of the marvellous creatures that thrive in the Sea of China, notably very large fish (possibly whales), giant tortoises, and monstrous snakes which land on the shores to swallow whole buffaloes and elephants, and Ibn Sa'id al-Maghribi, who gave the latitude and longitude of each place he visited and wrote much on the Indian Ocean islands and other Indian coastal towns and cities.

A 14th-century traveller, al-Dimashqi, gives very detailed accounts of the island of al-Qumr, also called Malay Island or Malay Archipelago. He says there are many towns and cities, rich, dense forests with huge, tall trees, and white elephants. Also there lives the giant bird called the *Rukh*, a bird whose eggs are like cupolas. The *Rukh* features in a story about some sailors breaking and eating the contents of its egg, so the giant bird chased after them on the sea, carrying huge rocks, which it hurled at them relentlessly, and the sailors only escaped with their lives under the cover of night. This story, like other accounts by travellers, formed the basis of many of the tales that enrich Islamic literature, such as *The Adventures of Sindbad the Sailor*, and *The Thousand and One Nights*.

'If anyone travels on a road in search of knowledge, Allah will cause him to travel on one of the roads of Paradise....'

Prophet Mohammad (pbuh) narrated by Abu al-Dardah





Left to right: Manuscript showing 10th-century Ibn Fadlan's *Risalah*, which was an account of his journey into northern Europe; artistic impression showing Ibn Battuta making supplications after reading the Quran. Muslims usually make these supplications (asking God) after reading the Quran or finishing prayers.

'The World is a book, and those who do not travel read only a page.'

St Augustine

The richness of these thousand-year-old accounts have even inspired writers and film makers. Ibn Fadlan was an Arab chronicler and in 921 the caliph of Baghdad sent him with an embassy to the king of the Bulgars of the Middle Volga. He wrote an account of his journey, and this was called *Risalah*. Like Ibn Battuta's *Rihla*, the *Risalah* is of great value because it describes the places and people of northern Europe, in particular a people called the Rus from Sweden in Scandinavia.

He wrote 'I have seen the Rus as they came on their merchant journeys and encamped by the Volga. I have never seen more perfect physical specimens, tall as date palms, blonde and ruddy; they wear neither tunics nor caftans, but the men wear a garment which covers one side of the body and leaves a hand free.'

This book inspired novelist Michael Crichton to write the film *The Thirteenth Warrior*. Many other Muslim travellers have inspired people in the modern day. Ibn Battuta's legacy now includes the world's largest shopping mall being named after him in Dubai, as well as a music CD by German band Embryo with tracks including *The Beat of Baghdad*.

Ibn Battuta

Ibn Battuta was only twenty-one on 13 June 1325 when he set out alone on his donkey at the beginning of a three-thousand-mile overland journey to Mecca from Tangier in Morocco. He left his family, friends and hometown, and wouldn't see them again for twenty-nine years. Some he never saw, because the plague reached them before he returned. He went to the corners of the Muslim world by walking, riding and sailing over seventy-five thousand miles, through over forty modern countries, and many know him as the Muslim Marco Polo.

His accounts have placed the medieval world in front of us, so we know that gold travelled from south of the African Sahara into Egypt and Syria, pilgrims continuously flowed to and from Mecca, shells from the Maldives went to West Africa, pottery and paper money came west from China. Ibn Battuta also flowed along with the wool and wax, gold and melons, ivory and silk, sheikhs and sultans, wise men and fellow pilgrims. He worked as a *qadi*, a judge, for sultans and emperors, and as

[illegible] Mali [illegible]

a pious Muslim, his driving force was faith and [illegible] the road of life, in great Islamic cities like [illegible] and Damascus, and from the great minds of his time.

It's reported that Prophet Mohammad (pbuh) had said 'seek knowledge, even as far as China' and Ibn Battuta took this literally. His journey became a kind of grand tour mixing prayer, business and adventure, and as a Muslim he understood codes of conduct throughout 14^{th} century Eurasia, which included equality, charity, trade, good citizenship, the pursuit of knowledge and faith.

When he returned to [illegible] three decades later he [illegible] recounting stories of distant [illegible]. Some simply would not believe him when he talked of these places. It was then that the sultan of Fez, Abu 'Inan, asked him to write down his experiences in a *Rihla*, a travel book [illegible] scribe Ibn Juzayy. They completed the task in two years.

[illegible] one of the greatest historical books ever [illegible] his account of medieval [illegible] West Africa is [illegible] record we have [illegible] today. Now we can see his world of the 14th century with our own eyes.

[illegible]

Navigation

IT IS WIDELY BELIEVED that the Chinese developed the compass for use in Feng Shui, and then mariners developed it further for use in navigation. The earliest evidence on the magnetic compass is found in the Persian work called *Collection of Stories* by Muhammad al-Awfi.

The year was 1233, and the voyage was over the Red Sea or the Persian Gulf. The compass was described as follows, 'a fish made of iron is rubbed with a magnetic stone and then put in a bowl filled with water; it rotates until it stops, pointing to the south.'

The first full description of the use of the magnetic compass for navigation in the Islamic world was by Baylak al-Qibjaqi in his *The Book of Treasure for Merchants who Seek Knowledge of Stones*, written in Egypt in 1282. He described the use of a floating compass during a sea voyage from Tripoli in Syria to Alexandria in 1242. He wrote that an iron needle is joined crosswise with a rush and put in a bowl filled with water. Then a magnetic stone is brought close to this device, and the hand holding the magnetic stone describes a circle clockwise above it. The cross of the needle and the rush follows this move. When the magnetic stone is suddenly removed, the needle is supposed to be aligned with the meridian.

Willow wood or pumpkin 'fish' designs that had magnetic needles were also mentioned. These were sealed with tar or wax to make them waterproof as they floated on water. These were known as wet compasses, but there was also the dry compass. Here, two magnetized needles are on opposite sides of a disc of paper, and in the middle is something like a funnel. This funnel rotates on an axis, which is pivoted in the middle of a box sealed with a plate of glass to prevent the disc of paper from dropping.

These designs and uses of the compass were taken to Europe by Muslim traders, who developed them further.

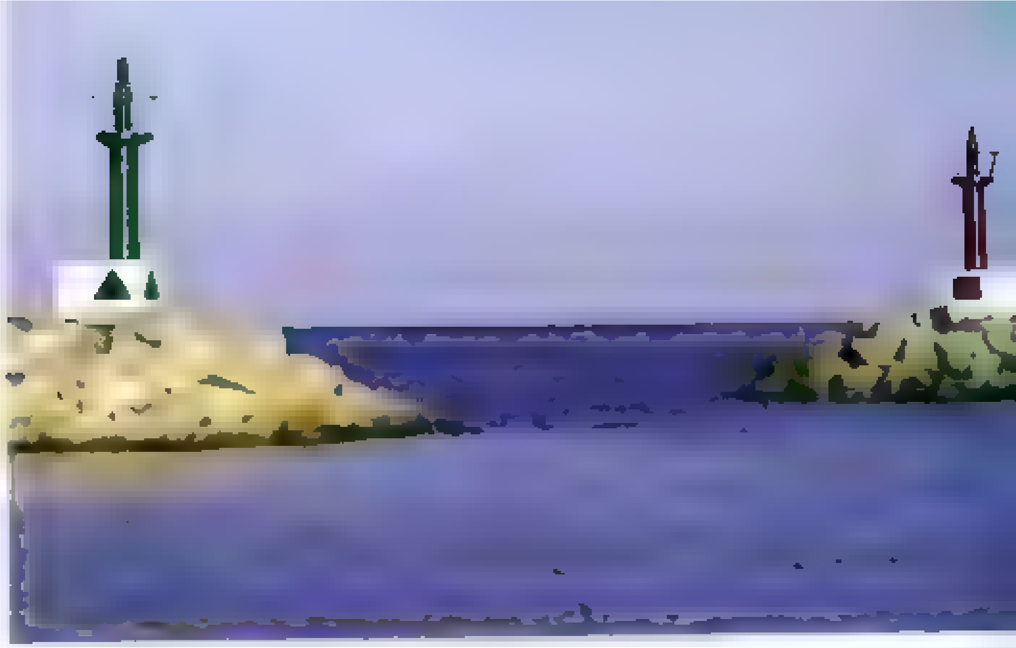
Below is a recent map of the Mediterranean, but in the 16th century, Piri Reis had also mapped this region in his *Naval Handbook*.

Master Navigators

As well as having developed navigation instruments, Muslims were also master navigators. Ibn Majid was such a person from Najd, in Arabia, in the 15th century. It ran in the family, and both his father and grand father were *Mu'allim*, or masters of navigation too, knowing the Red Sea expertly. He knew almost all the sea routes from the Red Sea to East Africa, and from East Africa to China. On these, he wrote at least thirty-eight treatises, some in prose, others in poetry, of which twenty-five are still available. These talked about astronomical and nautical subjects, including lunar mansions, sea routes, and latitudes of harbours.

But the most important navigator was the 16th-century admiral Piri Re'is, whose four hundred-and-fifty-year-old book of sailing instructions, *Kitab-ı bahriye*, is known in translation by three names as *The Book of the Mariner*, *The Naval Handbook* and *The Book of Sea Lore*. It was recently published in 1991 by the Turkish Ministry of Culture and Tourism, and this new printing includes a colour copy of the original manuscript, with the Ottoman text translated into Latin, modern Turkish, and English.

The Naval Handbook by Piri Re'is was a mariner's guide to the coasts and islands of the Mediterranean, which paved the way for modern sea travel. It was also known as a portolan, and was a comprehensive guide to nautical instructions for sailors, containing maps covering coastlines, waterways, ports and distances of the Mediterranean coast. It gave sailors instructions and good knowledge of the Mediterranean coast, islands, passes, straits, bays, where to shelter in face of sea perils, and how to approach ports and anchor. It also provided them with directions and precise distances between places.



It is the only full and comprehensive manual covering the Mediterranean and Aegean Seas ever done, with 219 detailed charts, and was the pinnacle of over two hundred years of development by Mediterranean mariners and scholars.

There were two editions of the book, the first came out in 1521, the second five years later. The first was primarily aimed at sailors; the second, on the other hand, was a gift from Piri Re'is to the sultan. It was full of craft designs, its maps drawn by master calligraphers and painters, and even in the 16th century it had already become collector's item. For over a century, copies were produced, becoming even more luxurious as they gave good descriptions of storms, the compass, portolan charts, astronomical navigation, the world's oceans, and the lands surrounding them. Interestingly, it also referred to European voyages of discovery, including the Portuguese entry into the Indian Ocean and Columbus's discovery of the New World.

There are around thirty manuscripts of this *Book of Sea Lore* scattered all over libraries in Europe, but most are of the first version.

More can be read about Piri Re'is in the 'Maps' section of this chapter, and also about Zheng He, the Chinese Muslim sea explorer

***The Naval Handbook* by Piri Re'is was a mariner's guide to the coasts and islands of the Mediterranean, which paved the way for modern sea travel.**

Sea Exploration

Over six hundred and thirty years ago, a man was born who would revolutionize sea exploration. His name was Zheng He, and he became the 'Admiral of the Chinese Fleet.' According to Gavin Menzies, author of *1421*, the recent book on Zheng He, he sailed throughout the Indian Ocean, navigating to Mecca, the Persian Gulf, East Africa, Ceylon (Sri Lanka), Arabia and throughout the Indian Ocean decades before Christopher Columbus or Vasco da Gama, with ships five times bigger.

Zheng He was a Muslim who helped transform China into the regional, and perhaps the world, superpower of his time. Within twenty-eight years of travel, he visited thirty-seven countries, making seven monumental sea voyages in the name of trade and diplomacy. The expeditions covered a distance of more than 50,000 kilometres, and his first fleet included 27,870 men on 317 ships. It was a small town or an entire football stadium on the move. Sailing with such a large fleet into largely unknown waters required great skill in management and sailing. There was no margin for error, and what he achieved is comparable to us going to the moon today.

A stone statue of Zheng He in Nanjing's Zheng He Memorial Hall

Zheng He was born and named Ma He, and his Muslim father and grandfather took pilgrimages to Mecca, which enabled him to grow up speaking both Arabic and Chinese. As a boy he was taken from his town of Kunming, which was Mongol, by the invading Chinese Ming dynasty. He was then castrated and became a eunuch, employed as a functionary in the Imperial household assigned to the retinue of Duke Yan or Zhu Di, a prince. Zhu Di later seized the throne and became the Emperor Yong Le.

Gavin Menzies said that 'Zheng He was a devout Muslim besides being a formidable soldier, and he became Zhu Di's closest advisor. He was a powerful figure, towering above Zhu Di; some accounts say he was over two metres tall and weighed over a hundred kilograms, with a "stride like a tiger's".'

Through dedicated service and for accompanying the duke on successful military campaigns, Ma He was awarded the supreme command of the Imperial Household Agency, and was given the surname Zheng. He was also known as the 'Three-Jewel Eunuch' (*San Pao Thai Chien*), which has Buddhist connotations (even though he was a Muslim), and was a mark of honour for this high palace official.

There were quite a few reasons why he went on the seven great 'Treasure Ship' voyages. There was scientific discovery and the search

Columbus's boat (75 feet long) compared with Zheng He's boat (440 feet long)

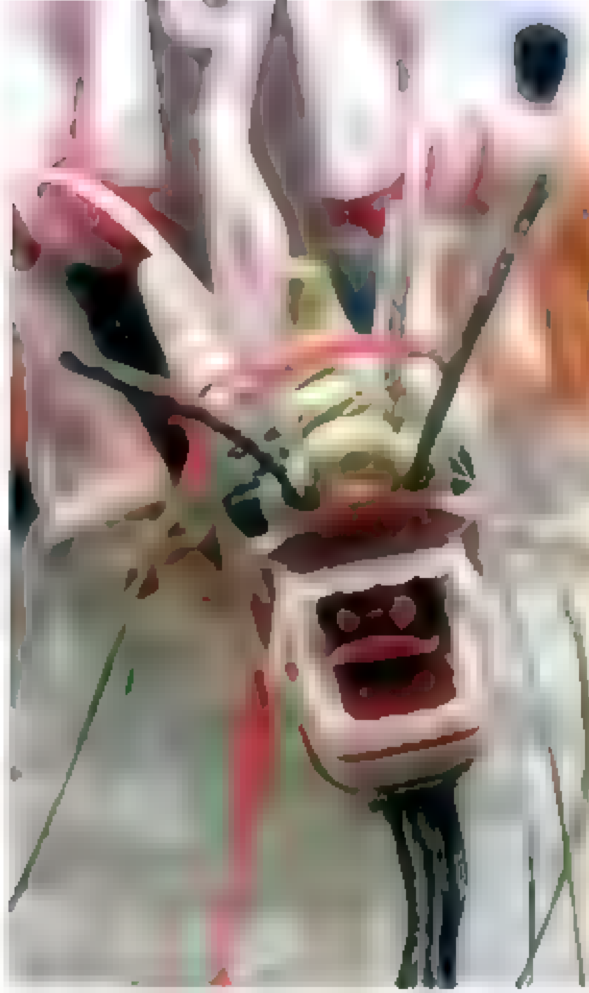
for gems, minerals, plants, animals, drugs and medicine, which became increasingly important as the voyages multiplied. They wanted to improve navigational and cartographical knowledge of the world and had a desire to show all foreign countries that China was the leading cultural and economic power. So overseas trade was encouraged, and this meant that other countries saw the massive Chinese ships, and it boosted their prestige. Other nations swore allegiance to China through diplomacy, with local and regional leaders acknowledging 'overlordship' of the Imperial power. The country would then send envoys to pay tribute to the emperor.

Zheng He made these voyages between 1405 and 1433, and he was joined by two other able eunuch leaders Hou Hsien and Wang Ching Hung.

What was amazing about the voyages was that they were huge and fully organized. Zheng He wrote that 'sixty-two of the largest ships were 440 feet long, and at broadest beam 180 feet.' This is Ming units (1.02ft) so it would be 449 feet long and 184 feet wide in our measurements. Zheng He also wrote that they were manned by four hundred and fifty to five hundred men each, including sailors, clerks, interpreters, soldiers, artisans, medical men and meteorologists. On the fourth voyage, he set out with thirty thousand men to Arabia and the mouth of the Red Sea.

鄭和

The name in Chinese of the Muslim Chinese Admiral, Zheng He



Far right: 15th-century Zheng He and his crew used this navigation chart as they charted the routes taken during his voyages.

The Chinese shipbuilders realized that the gigantic size of these ships would make manoeuvring difficult, so they installed a balanced rudder that could be raised and lowered for greater stability. Ship builders today do not know how the Chinese built a framework, without iron, that could carry a 400-foot long vessel, and some doubted the ships ever existed, but in 1962, the rudderpost of a treasure ship was found in the ruins of one of the Ming boatyards in Nanjing. This was thirty-six feet long. Doing reverse calculations, using the proportions of a typical traditional junk, the estimated hull for this rudder would be five hundred feet.

On board these mighty vessels were large quantities of cargo including silk goods, porcelain, gold and silverware, copper utensils, iron implements and cotton goods, live animals including giraffes, zebras or 'celestial horses,' oryx or 'celestial stag,' and ostriches or 'camel birds,' watertight bulkheads to hold live fish and also make bath houses, and otters that were sent out to round up fish into large nets. The ships were able to transfer water from floating water tankers to their holds, and they could communicate through flags, lanterns, bells, carrier pigeons, gongs, and banners.

A Ming account of the voyages says: 'The ships which sail the Southern Sea are like houses. When their sails are spread they are like great clouds in the sky,' and they were described collectively as 'swimming dragons,' because all were dotted with dragons' eyes to help them see.

By the end of his fleet's seven voyages, China was unrivalled in naval technology and power, and China and India together accounted for more than half of the world's gross national product. China also benefited

from many exotic species being introduced, like the first giraffe from Africa. It was initially misidentified as the qilin, the unicorn central to Chinese mythology. According to Confucian tradition, a qilin was a sage of the utmost wisdom, and benevolence was felt in its presence.

It is believed that Zheng He died on his way back in 1433, in India. With his death and the coming of the Confucian Era, the Chinese Empire became inward looking and eventually sea-going trade was banned. In less than a hundred years, it was a capital offence to set sail from China in a multi-masted ship. In 1525, the Chinese government ordered the destruction of all ocean-going ships. The greatest navy in history, which once had 3,500 ships (the US Navy today has around three hundred), was gone.

In 1985, at the five hundred and eightieth anniversary of Zheng He's voyages, his tomb was restored. The new tomb was built on the site of the original tomb in Nanjing, and reconstructed according to the customs of Islamic teachings. At the entrance to the tomb is a Ming-style structure, which houses the memorial hall. Inside are paintings of the man himself and his navigation maps.

To get to the tomb, there are newly laid stone platforms and steps. The stairway to the tomb is of twenty-eight stone steps divided into four sections, with each section having seven steps. This represents Zheng He's seven journeys to the West. Inscribed on top of the tomb are the Arabic words *Allahu Akbar*, or God is Great.

There were no other ships in the world as big as, or with as many masts as, Zheng He's. These were floating cities on the move. Most of the ships were built at the Dragon Bay shipyard near Nanjing, the remains of which can still be seen today.

Zheng He's Seven Epic Voyages

1. 1405–1407: Visited Champa (Indo-China), Java and Sumatra, Ceylon and Calicut, India.

2. 1407–1409: Sailed to Siam and India, stopping at Cochin.

3. 1409–1411: Went to all the usual places in the East Indies using Malacca as a base, visiting Quilon in India for the first time.

4. 1413–1415: The fleet split up. Some went to the East Indies again, others (based in Ceylon) went to Bengal, the Maldives, and the Persian sultanate of Ormuz. This voyage provoked so much interest that a huge number of envoys visited Nanjing in 1416. A huge fleet the following year had to take them home again.

5. 1416–1419: The Pacific squadrons went to Java, Ryukyu and Brunei. The Indian-based ones went to Ormuz, Aden, Mogadishu, Mombasa and other East African ports. It was on this trip that the giraffe was brought back.

6. 1421–1422: Sailed the same seas as before, including more ports in South Arabia and East Africa. The fleet visited thirty-six states in two years from Borneo in the east to Zanguebar in the west. This suggests they split up again, using Malacca as the main rendezvous port, which, before the advent of the radio, is incredible.

7. 1431–1433: This final voyage, when Zheng He was sixty, established relations with more than twenty realms and sultanates from Java to Mecca to East Africa. No one knows how far down the East African coast the Chinese went, but there are accounts that they rounded the Cape.

'We have ... beheld in the ocean huge waves like mountains rising sky-high, and we have set eyes on barbarian regions far away, hidden in a blue transparency of light vapors, while our sails, loftily unfurled like clouds, day and night continued their course rapid like that of a star, transversing the savage waves as if we were treading a public thoroughfare.'

Zheng He in his biography, *Ming Shih*

Code Breaking and Cryptography

COMMUNICATING TOP SECRET INFORMATION is a precarious and risky process, so to avoid vital statistics falling into the wrong hands, messages are scrambled, masked and coded so only those with the right information or tools can read them. This process is known as cryptography, the scrambling of a message is known as encryption and the de-scrambling is decryption. For anyone other than the intended recipient, the message is meaningless, unless that person uses cryptanalysis to break the code.

A most famous case of encryption was during World War II when the Germans used a typewriter-like machine called Enigma to encrypt military messages before playing them on the radio. These were decrypted by a group of savvy Polish code breakers from the Cipher Bureau and British code crackers from Bletchley Park, all made famous in the recent film 'Enigma'.

These 20th-century problem solvers were carrying on the code-breaking tradition first written about by 9th-century polymath al-Kindi from Baghdad. At this time the post was delivered by birds, so messages had to be light in weight, and the confidential ones were encrypted.

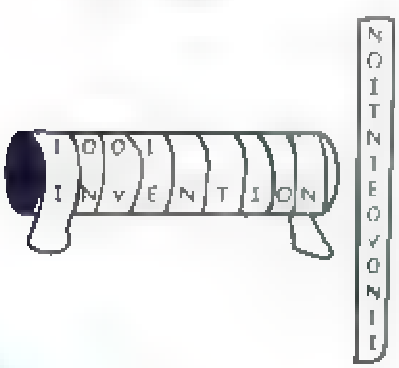
Cryptography and cryptanalysis have certainly become more sophisticated today than in the early days, but the basic principle of changing and substituting characters is still used by cryptographers today.

In the 6th century BCE, the Greeks came up with an ingeniously simple device for encrypting messages. They used a fixed-width stick called a 'scytale', which they wrapped with a long piece of paper and wrote on it horizontally. They then unwrapped the paper and sent it to the receiver, who could only read it if they had a scytale of exactly the same width to wrap the paper around. If the stick was wider or narrower, the message could not be read.

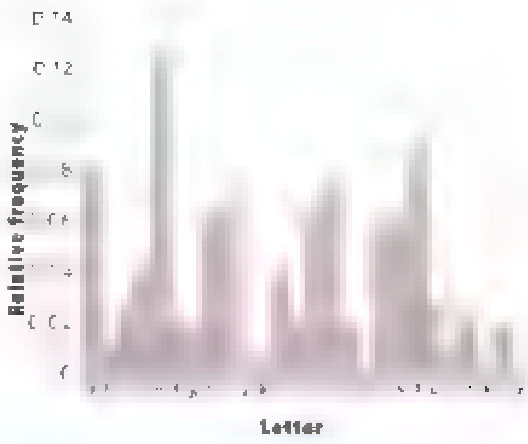
The real cryptanalysis milestone was passed by al-Kindi, who revolutionized the area when he wrote *A Manuscript on Deciphering*

Right: An Enigma machine that was used to encrypt military messages in World War II. It was al-Kindi in the 9th century who laid the foundations of cryptography.

Below: A typical Greek scytale used to pass along a coded message.



The Frequency Analysis chart.



Cryptographic Messages. Part of this included a description of the method of frequency analysis, which means he noticed that if a normal letter is replaced with a different letter or symbol, the new letter will take on all the characteristics of the original one. So if all a's that appeared became t's, and all th's were replaced with g's, they would still have the features of the letter(s) they replaced. A word like athlete would become tglete! Even though the letters change, what cannot be disguised are certain characteristics a letter has, like its frequency of occurrence.

If we look at the English language the letter e is the most common letter, accounting for thirteen per cent of all letters. So, if e is replaced by symbol #, # would become the most common symbol, accounting for 13% of the 'new' symbols. A cryptanalyst can then work out that # actually represents e.

From studying the Arabic text of the Quran closely, al-Kindi noticed the characteristic letter frequency, and laid cryptography's foundations which led many cryptographers from European Renaissance states to devise several schemes to defeat it. Even though al-Kindi discovered methods that enabled greater encryption and code breaking eleven hundred years ago, the actual word 'cryptanalysis' is relatively recent and was first coined by a man called William Friedman in 1920.

Frequency analysis is now the basic tool for breaking classical ciphers or codes that use the basic, plain text alphabet. It relies on linguistic and statistical knowledge of plain text language, and good problem solving skills.

Modern ciphers are a lot more complex, but back in the days of World War II, Britain and America recruited code breakers by placing crossword puzzles in major newspapers and running contests for who could solve them the fastest.

'One way to solve an encrypted message, if we know its language, is to find a different plaintext of the same language long enough to fill one sheet or so, and then we count the occurrences of each letter. We call the most frequently occurring letter the 'first,' the next most occurring letter the 'second,' the following most occurring the 'third,' and so on, until we account for all the different letters in the plaintext sample.... Then we look at the cipher text we want to solve and we also classify its symbols. We find the most occurring symbol and change it to the form of the 'first' letter of the plaintext sample, the next most common symbol is changed to the form of the 'second' letter, and so on, until we account for all symbols of the cryptogram we want to solve.'

Al-Kindi in his 9th century A Manuscript on Deciphering Cryptographic Messages

'The birth of cryptanalysis required a society which has reached a high standard of development in three disciplines, namely linguistics, statistics and mathematics. These conditions became available at the time of al-Kindi who had command of these three disciplines and more.'

Dr Simon Singh
The Code Book, 1999

Weaponry

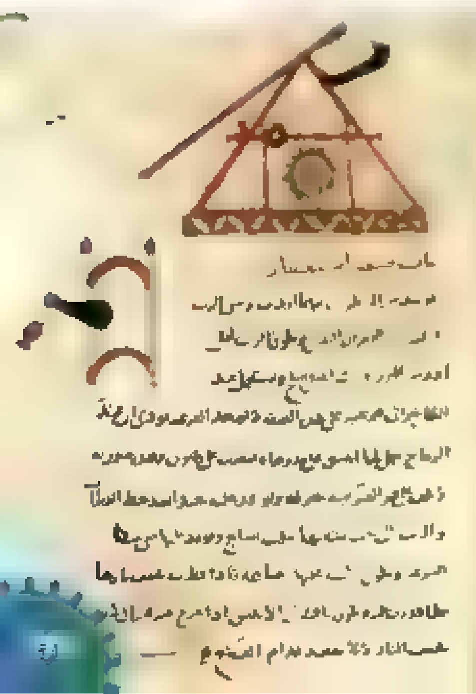
Military talk in the 13th century was sophisticated, and discussions included grenades, sulphur bombs, cannons, rockets and torpedoes. One of the most important books on military technology was *The Book of Horsemanship and Ingenious War Devices* by the Syrian scholar Hasan al Rammah, written around 1295. It was packed full of weapon diagrams, including the first documented rocket, a model of which is exhibited at the National Air and Space Museum in Washington DC, USA today.

The Chinese knew about gunpowder. They developed saltpetre, one of gunpowder's ingredients, but probably only used it in fireworks. As Amani Zain from the BBC's *What the Islamic World Did for Us* says, research has shown that Muslim chemists did develop a powerful formula for gunpowder and may well have used it on the first firearms.

The Chinese didn't use it in explosions because they couldn't get the right proportions, nor could they purify potassium nitrate. It wasn't until 1412 that Huo Lung Ching wrote the first Chinese book detailing explosive proportions. About a hundred years earlier, Hasan al Rammah's book was the first to explain the purification procedure for potassium nitrate, and it describes many recipes for making exploding gunpowder.

For the Islamic Armies led by Baybars in 1249 the use of gunpowder in war proved decisive against the invading crusaders. At the battle of al Mansura in Egypt, Muslim incendiary devices were so terrifying and destructive that the French Crusader Army was routed and King Louis IX was taken prisoner, reports Amani Zain on the BBC's *What the Islamic World Did for Us*.

Left to right: A trebuchet for flinging missiles from a 13th-century [illegible] al [illegible] from a 14th-century *Manual on Armoury* by Ibn Aranbugha al Zardkash; a [illegible] crossbow from a 14th-century *Manual on Armoury* by Ibn Aranbugha al Zardkash



Without Hasan al-Rammah's book, cannons couldn't have developed. By the 15th century, the cannons used by the Ottomans were awesome and today the Fort Nelson Museum in London has a huge bronze cannon weighing eighteen tonnes. It was originally cast in two pieces, and screwed together, to make it easier to transport because its overall length is over five metres, with a diameter of 0.635m. The length of the barrel alone is over three metres and the gunpowder reservoir is 0.248m in diameter. No such split guns existed in Europe before this one.

This novel cannon was cast in 1464 by the order of Sultan Mehmed II. He was very interested in firearms, especially in cannons. During his siege of Constantinople, he ordered his cannon master to cast large cannons that had never seen before and this one could fire cannon balls one mile.

On the muzzle is inscribed in Arabic writing: Help, O Allah, The Sultan Mohammed Khan son of Murad. The work of Kamina Ali in the month of Rajab. In the year 868 (of the Hejira calendar), or 1464 CE.

Sultan Mehmed's cannon ended up in a London museum because, after unsuccessful attempts by the English for sixty years to convince the Ottomans to sell it, Queen Victoria personally asked Sultan Abdul Aziz for it during his visit to Europe. One year later, the sultan sent it as a gift. It was transported from the Dardanelles to London and placed in the Museum in 1868. Queen Victoria perhaps wanted it because it was called the 'most important cannon of Europe.'

Muslims also built rockets and the first torpedo. The rocket was the so-called 'self-moving and combusting egg' and the torpedo was a cleverly modified rocket designed to skim along the surface of the water. It was called 'the egg, which moves itself and burns'

To make gunpowder: 'Take from white, clean and bright (or fiery) barud (saltpetre) as much as you like and two new (earthen) jars. Put the saltpetre into one of them and add water to submerge it. Put the jar on a gentle fire until it gets warm. Skim off the scum that rises (and) throw it away. Make the fire stronger until the liquid becomes quite clear. Then pour the clear liquid into the other jar in such a way that no sediment or scum remains attached to it. Place this jar on a low fire until the contents begin to coagulate. Then take it off the fire and grind it finely.'

Hasan al-Rammah describes a complete process for the purification of potassium nitrate in his book The Book of Horsemanship and Ingenious War Devices

and Hasan al-Rammah's illustrations and text show two sheet-iron pans were fastened together and made tight by felt. This made a flattened pear-shaped vessel that was filled with 'naphtha, metal filings, and good mixtures [probably containing saltpetre], and the apparatus was provided with two rods and propelled by a large rocket.' The two rods would probably have acted as tail rudders, while a spear at the front would lodge into the wooden hull of an enemy ship to secure it before exploding.

A traction trebuchet for hurling missiles from a 14th century *Manual on Armoury* by Ibn Aranbugha al-Zardkash

Cannon with adjustable [illegible] from a 14th century *Manual on Armoury* by Ibn Aranbugha al-Zardkash

Castles and Keeps

CITIES TODAY are no longer designed with a potential siege mentality, but look around the world and the fortifications of the past are now accessible to us as tourist sites, like the Tower of London.

Even though the European crusaders had superiority in ammunition and manpower when they went to Jerusalem, the Muslims were able to sustain attacks, and for a considerable time. The impressiveness of their military structures and castles was not lost on the Europeans, who took these architectural ideas home with them. The invincible designs of the castles of Syria and Jerusalem were imitated in the western lands with key features like round towers, arrow slits, barbicans, machicolations, parapets and battlements soon appearing.

Before the crusaders lost vital battles to Saladin in the 12th century, most Christian military towers had square keeps. Saladin's **round towers** impressed upon the crusaders the need to leave out projecting angles, because they encouraged flanking fire. The first recorded example to abandon the square and adopt the round tower was Saone, which was built in 1120.

The **loopholes** or arrow slits in fortified walls were first used around 200 BCE by Archimedes to protect Syracuse. These long and narrow slits meant a bowman could shoot at the enemy, but be protected from returning fire. They were also used in the fortifications of Rome, and were improved and popularized by Muslims in the Palace of Ukhaydar, an 8th century Iraqi Palace, and the 9th century Sussa Ribat in Tunisia. The first recorded use of them in England was in London in 1130.

The **barbican** is a walled passage added to the entrance of a castle in front of the main defensive wall. This delayed the enemy's entrance into the castle, and also gave the defenders more opportunities to hold up the attackers by forcing them into a small space. The enemy could then be attacked from above and from the sides. The word barbican is taken from the Arabic *bab al-baqarah* meaning 'gate with holes'.

Left to right: The Tower of London; an early 16th century castle, one of two, that would be wheeled into a large field and would hold 60 fighting men in full battle dress, ready to practise military manoeuvres; a Bavarian Castle in Germany.

The returning crusaders often brought Muslim masons with them, and they built these features into the defences of European castles in the 12th century. There were also peaceful periods in the Crusades when the architects and builders with the crusaders could watch and learn how the local Muslims designed and built their fortifications.

Christian masons also had to earn their living, especially in times of peace, and some of them were hired by Muslims to help in repair or in new constructions. The story of Eudes de Montreuil demonstrates such an encounter as he accompanied St Louis on crusade between 1248 and 1254, and worked at Jaffa and then in Cyprus.

Muslims also used **bonding columns** inside masonry to strengthen the walls. They had taken and developed this technique from the Roman architect and engineer Marcus Vitruvius Pollio. The walls of the harbour of Acre were built with them. It was the Emir of Egypt, Ahmad ibn Tulun, who in 883 instructed that the harbour be built with the strongest form to repel the waves and enemy attacks. So timber beams were inserted into the masonry of the wall, like steel is today, to bind its two faces together. After the crusaders' occupation of Acre in 1103, they learnt this construction technique and introduced it in their military architecture, such as that in Caesarea in 1218.

Machicolations were a big feature in Muslim defences. These were holes or gaps in the overhang of a **parapet**. Through them defenders could fire arrows and drop stones or oil on their attackers. They appeared first in Qasr al-Hayr near Rusafa in Syria in 729, and came to Europe in the 12th century, first at the Chateau Gaillard built by Richard the Lionheart following his return from the crusade. Then they made it to Norwich in 1187 and to Winchester six years later. Like many of these defences, the returning crusaders borrowed the idea from the Muslim world.

Battlements are a series of stone indentations and raised sections added to the tops of walls of buildings. Originally they gave cover to wall defenders, but in modern times they are decorations. These also came to Europe in the 12th century with returning crusaders. There's a great likeness between the battlements of the 15th-century church at Cromer in Norfolk, the Palazzo Ca' d'Oro in Venice and some buildings in Cairo, such as the 13th-century Zayn al-Din Yusuf Mosque, and the 10th-century al-Azhar Mosque respectively.

Although the Crusades were a bloody time there were interspersed moments of peace, where ideas were talked about and swapped. The vast movement of people also meant the movement of these ideas, which helped eastern concepts migrate to the west.

A round tower in Podzamcze, Poland

A tower of a citadel in Shiraz, Iran

Social Science and Economy

IBN KHALDUN was one of the last scholars of classical medieval Muslim civilization. In many ways his writing, family story and life reflect with great perfection the changes that caused the decline, and eventual fall, of medieval Islamic civilization. Born in Tunis in 1332 and dying in Cairo in 1406, he explained how Islamic civilization was undone.

He began by looking at the various invaders who undermined it, and how his ancestors were themselves affected by such invasions. Up until 1248, they had lived in Seville, then the Spanish Christians advanced, and their home was given up as they fled. These ancestors escaped to North Africa, where his parents died of another of the woes that afflicted everyone in that age, not only Muslims – the plague.

Ibn Khaldun then left his native Tunisia for Egypt, in 1382, and his own family came out after him, but they fell victim to yet another of the scourges of the day, piracy. His family were killed or taken captive, and he never saw them again, nor did he ever say a word about them.

The last years of Ibn Khaldun's life correspond to possibly the last years of classical Muslim scholarship and bright civilization. By the early 15th century, having lost Sicily and Spain, and having suffered the Crusades and the Mongol invasions, the Muslim world now suffered the most devastating onslaught of Timur The Lame (also known as Tamerlane), whose effects were in part witnessed by Ibn Khaldun.

Modern artistic impression of Ibn Khaldun

Despite the demands of his work as a judge and diplomat, he managed to continue his academic research, and produced his world history called *Book of the Lessons and Archive of Early and Subsequent History*. This became known as *al-Muqaddimah* or *Introduction*.

The *al-Muqaddimah* is a gigantic endeavour, a discourse on universal history. Ibn Khaldun explored and implemented the idea that the documentation of history is not just a list of correct facts, but is dependent on who's interpreting them, what region they come from and when, as well as their impartiality. This was a revolutionary approach to writing history, and his methodology is still used by historians today. He completely rejected partiality and unchecked facts. In this way, he brought in a rigorous new dimension to scholarship and the social sciences, which provided the basis for arguments before they could become accepted as scientific.

The great book was made up of six sections following a long introduction. The first section dealt with society in general, its various types, its geographical distributions, and the regions of civilized earth. The second looked at nomadic societies, including savage tribes. The third was a discourse on dynasties, the caliphates, the spiritual and temporal powers, and political ranks. The fourth section discussed non-nomadic societies, cities and provinces. The fifth dealt with crafts, ways of making a living, and other economic activities, while the sixth looked at the various classifications of the sciences, and methods of learning and teaching. This entire book was finally translated into English in 1957.

One of his best-known studies relates to the rise and decline of civilizations, and it is this that laid down the foundations of social science, the science of civilization and sociology. He explains how civilization and culture breed their own decline. They have

Ibn Khaldun used a revolutionary approach to writing history and his methodology is still used by historians today.

Ibn Khaldun resided in North Africa and spent the last years of his life in Cairo. Here he produced his world history known as the *Muqaddimah*. This study laid down the foundations of social science.

The second section of Ibn Khaldun's book studies nomadic [illegible]

a natural development into luxury, which produces moral laxity and depravity, until decay sets in, ending in dissolution of the formerly healthy society, which gradually becomes corrupted and hurries to its extinction.

Then he elaborated his social theory further, suggesting that the rise of a social group or even a state starts with a social concept he termed as '*asabiyah*', or tribalism. 'Political leaders and dynasties attain their eminence by virtue of their ability to concentrate the group feeling upon themselves, and thereby profit from its natural bent for the acquisition of power. The achievement of political predominance sets in motion a process of territorial over-expansion that dilutes the group support for the dynasty. More important, it also marks the beginning of an inevitable three-generation cycle of weakening the dynasty's moral fibre. The dynasty becomes alienated from its supporters, and its realm falls prey to others who are fired by a strong and unspoiled group feeling.'

He saw that society or civilization had a cyclical nature. It rose up because of a common need for protection and domination, reached a peak when the social bonds were at their strongest, before declining, and perished when group support and social bonds became diluted because of unhealthy competition and corruption at times of prosperity.

In Ibn Khaldun's mind, the only thing that could counteract the disintegrative forces, inherent in every nation, was religion. He said that Islam gave a community a lasting spiritual content, a complete answer to all problems of life; that it furnished the complete answer to his empirical inquiry into the organization of the human race. He saw religion as an absolute necessity for a really united and effective state.

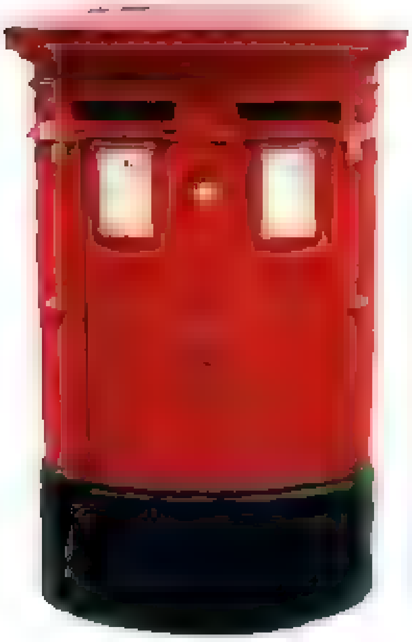
He was also ahead of his time in economic theory. Four centuries before Adam Smith, Ibn Khaldun had already concluded that labour was the source of prosperity. He had also distinguished between the direct source of income in agriculture, industry and commerce, and the indirect source of income of civil servants and private employees. These concepts may seem like second nature today, but they were groundbreaking seven hundred years ago, and have paved the way for classical economics and their models relating to consumption, production, demand, cost and utility.

[illegible] a Moorish castle, Spain. Ibn Khaldun explains the [illegible]

[illegible]

Human beings require cooperation for the preservation of the species, and they are by nature equipped for it. Their labour is the only means at their disposal for creating the material basis for their individual and group existence. Where human beings exist in large numbers, a division of activities becomes possible and permits greater specialization and refinement in all spheres of life. The result is umran (civilization or culture), with its great material and intellectual achievements, but also with a tendency toward luxury and leisure which carries within itself the seeds of destruction'

From 14th-century Ibn Khaldun's al Muqaddimah



Post and Mail

ONCE UPON A TIME, messages were delivered by word of mouth, by hand or bird, with smoke signals, or engraved on tablets of stone. They didn't bleep, ring, arrive to the sound of the latest number one pop song, or at the click of a mouse.

A major breakthrough in communications, probably like the internet is today, happened in Baghdad when the Abbasid caliphs used carrier pigeons, because they noted the tendency of certain pigeons to fly straight home from wherever they may be. A fast one-way postal service, always back to base, became possible. Through selective breeding of suitable birds, the homing pigeon developed, and a Mamluk caliph, Baybars, five hundred years later made this a very effective form of delivering messages.

The Muslim scholar Ibn 'Abd al-Dhahir even wrote a book on carrier pigeons. He mentions that normally there would be about one thousand nine hundred pigeons in the lofts of the citadel of Cairo, the communication nerve centre of the time.

Al-Nuwayri, a Muslim chronicler, tells the story of a 10th-century Fatimid caliph called 'Aziz who one day, in Cairo, felt a desire to eat fresh cherries of a kind grown in Antioch. The order was sent by carrier pigeon to Baalbek, near Antioch, and from there, six hundred pigeons were released, each with one cherry in a silk bag tied to each leg. Just three days after expressing his desire, the caliph was served a large bowl containing one thousand two hundred fresh cherries from Lebanon, which had arrived by special 'air mail' delivery.

Pigeons used to be the post carriers

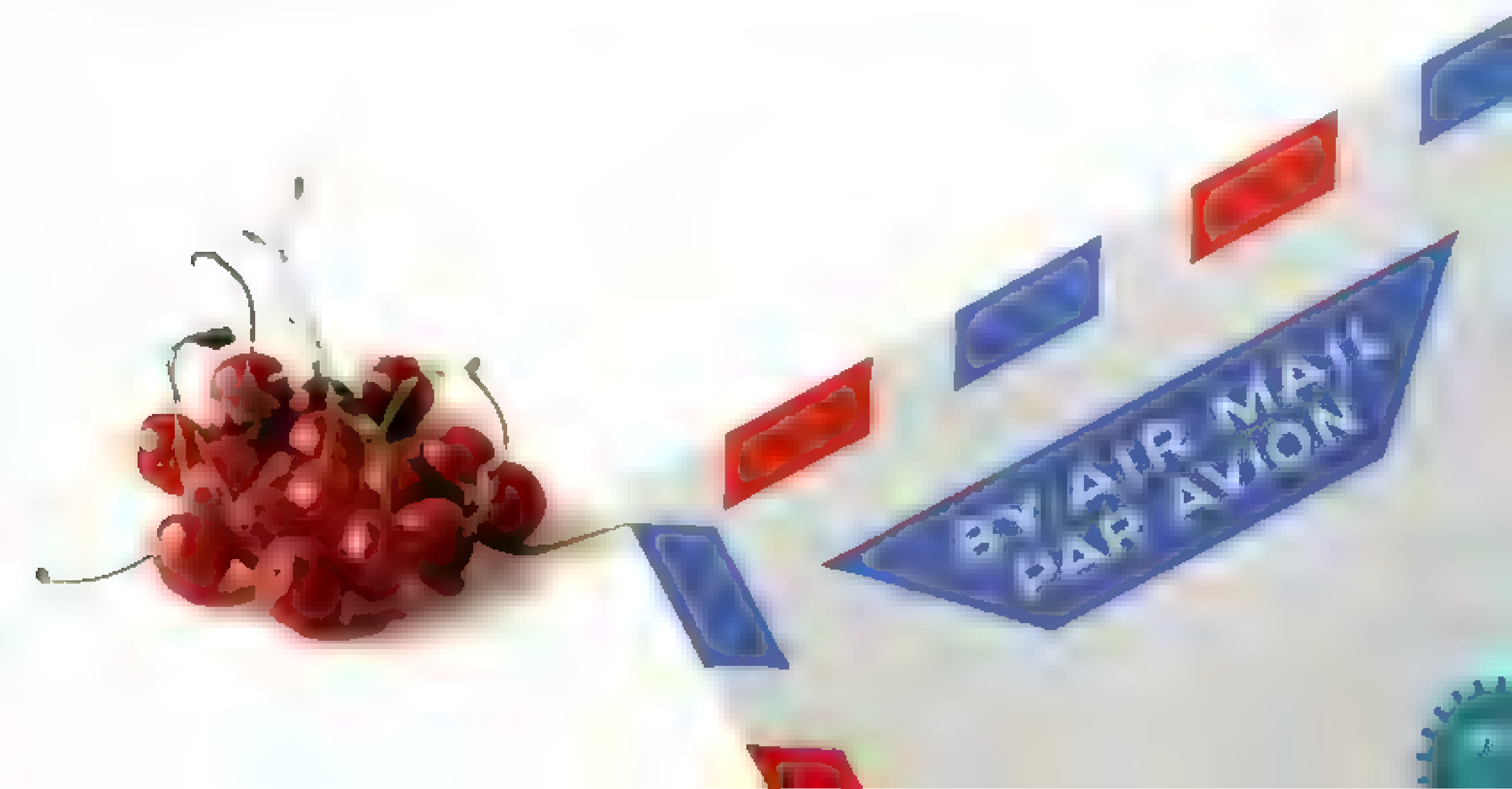
The use and breeding of the homing pigeon has become a global pastime, with racing pigeons frequenting the sky. But pigeons have also had a practical wartime function in Europe. Pigeon post was in operation when Paris was besieged during the Franco-Prussian War of 1870-1871. The four and a half month siege meant that the post couldn't be delivered by the usual means. The only successful method was by the time-honoured carrier pigeon, which took thousands of messages, official and private, in and out of the city.

In 14th century medieval India, it wasn't pigeons but couriers, like modern day relay runners, who took messages to the Muslim sultan sitting in Delhi. Ibn Battuta, the roving explorer of the 14th century, explains that a man carrying a rod with copper bells on the top would sprint as fast as he could for a third of a mile, and on hearing the bells the next man would get ready to take the mail. In all, it only took five days for a message to get from the eastern edge of India to the capital.

As Ibn Battuta travelled over the vast Muslim Empire, he found many ingenious ways to send goods and messages. He sent a payment to his son in Damascus with a trader he met in Mecca, feeling he could trust the man with his money because he was a fellow Muslim, and because he came from the same town of Tangier.

So, even though people were miles apart a thousand years ago, they were connected with the technology of their time.

A thousand years ago a Fatimid caliph had fresh cherries delivered by six hundred pigeons. Each had a silk bag holding two cherries each.



07 UNIVERSE

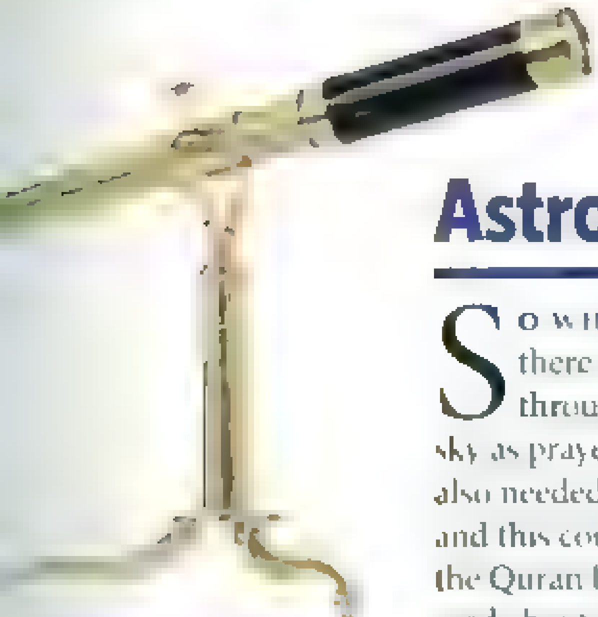
> 'It is He who created the Night and the Day, and the sun and the moon: all (the celestial bodies) swim along, each in its orbit.'
>
> (Quran (21:33))

The night sky and the mysteries of the universe have inspired poetry, music, philosophy and science for thousands of years and the Muslims of a millennium ago were no different.

The wonders of the universe inspired the first successful manned flight twelve hundred years ago as others were keeping a watchful eye on the night sky. They needed to know the times of the daily prayers that depend on the Sun's position, the direction of Mecca from every geographical location, and the Moon's cycle for the Muslim lunar calendar.

[illegible] Muslims also made epoch-making discoveries like the first record of a star system outside our own galaxy and the third inequality of the Moon's motion, and developed instruments that laid the foundation for modern day astronomy. These included celestial globes, armillary spheres, universal astrolabes and sextants. This all began in the 8th century with the first observatory and accurate astronomy tables.

Today these stargazing scholars, along with other eminent Muslim minds all mentioned in this book, are remembered as we look up because areas of the Moon bear their names and over one hundred and sixty-five stars have Arabic titles.



Astronomy

So why did Muslims spend so much time looking at the sky? Well there was a practical need to determine the times of the daily prayers throughout the year and these times depend on the Sun's position in the sky as prayers are at dawn, midday, afternoon, sunset and evening. Muslims also needed to know the direction of Mecca from every geographical location, and this could be done by observing the position of the Sun and Moon. Then the Quran had some major revelations about the heavens, which you can read about in this Universe chapter, that needed to be explored. And a final motivation was the calendar.

The Muslim calendar is a lunar calendar, so the months change according to the phases and position of the Moon. Each month begins with the first sighting of the crescent Moon. This is especially important in the Muslim holy month of Ramadan when Muslims fast during the day for one month.

From these religious motivations astronomy became a main concern for Muslim scholars a thousand years ago, and what they produced lasted for centuries. During the Renaissance, Regiomontanus, a celebrated 15th century mathematician and astronomer had to rely on Muslim books for his sources, whilst Copernicus refers repeatedly in his book *De Revolutionibus* to al-Zarqali and al-Battani, Muslim astronomers of the 11th and 10th centuries.

Most of the great astronomical discoveries happened in observatories in the East, but for the three hundred years that Muslims ruled Toledo in Spain, it was the centre of world astronomy. The new astronomical tables made there were used in Europe for two centuries.

Observing the sky was an intense activity and it happened on a daily basis when the Sun and Moon would be studied as they tracked across the heavens. This helped to determine solar parameters and produced information on the longitudes and latitudes of the planets whose measurements were made at intervals of two weeks.

In 9th century Baghdad Caliph al-Ma'mun set up an intellectual academy, the House of Wisdom, to translate manuscripts, which you can read about in the School chapter. Among the first works translated into Arabic was the Alexandrian astronomer Ptolemy's *Great Work*, which described a universe in which the Sun, Moon, planets and stars revolved around Earth. *Almagest*, as the work

was known to Arabic scholars, became the basis for cosmology for the next five hundred years. Yet the Muslims developed and went far beyond the Greek mathematical methods found in this treatise. In particular in the field of trigonometry, the advances made in Muslim lands provided the essential tools for the creation of western Renaissance astronomy.

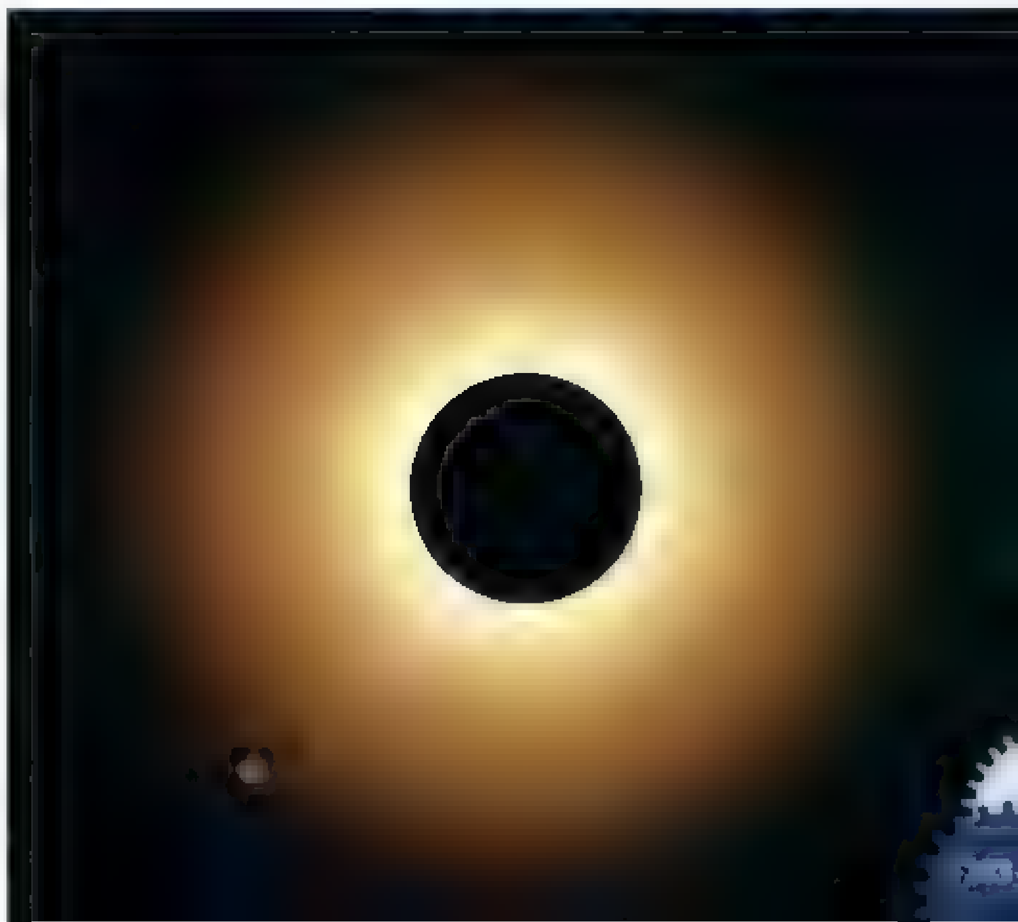
There were many Muslim astronomers who contributed hugely to the field of studying the heavens, laying the foundation for astronomers in the future, but these are [illegible] individuals [illegible].

Al-Battani (known in the West as Albategnius, who died 929 CE) wrote *The Sabian Tables*, which was a very important work for centuries after him. His work also included finding the new Moons, calculation of the length of the solar and sidereal year, the prediction of eclipses and the phenomenon of parallax. He also popularized, if not discovered, the first notions of trigonometrical ratios used today and made serious alterations to Ptolemy's theories, which had been used as the main astronomical works until then. He made the important discovery that the motion of the solar apogee, or the position of the Sun among the stars at the time of its greatest distance from the Earth, was not what it had been in the time of Ptolemy. The Greek astronomer placed the Sun at longitude sixty-five degrees, but al-Battani found it at longitude eighty-two degrees. This discrepancy was a distance too great to be accounted for by any inaccuracy of measurement. Since today we know it is because the solar system is moving through space. Then though, it was still believed that the Earth was the centre of the universe so this conclusion couldn't be made.

Al-Biruni lived between 973 and 1048. He stated that the Earth rotated around its own axis, calculated the Earth's circumference, and fixed scientifically the direction of Mecca from

'After having lengthily applied myself in the study of this science, I have noticed that the works on the movements of the planets differed consistently with each other, and that many authors made errors in the manner of undertaking their observation, and establishing their rules. I also noticed that with time, the position of the planets changed according to recent and older observations; changes caused by the obliquity of the ecliptic, affecting the calculation of the years and that of eclipses. Continuous focus on these things drove me to perfect and confirm such a science.'

Al-Battani, astronomer and mathematician (858–929 CE)

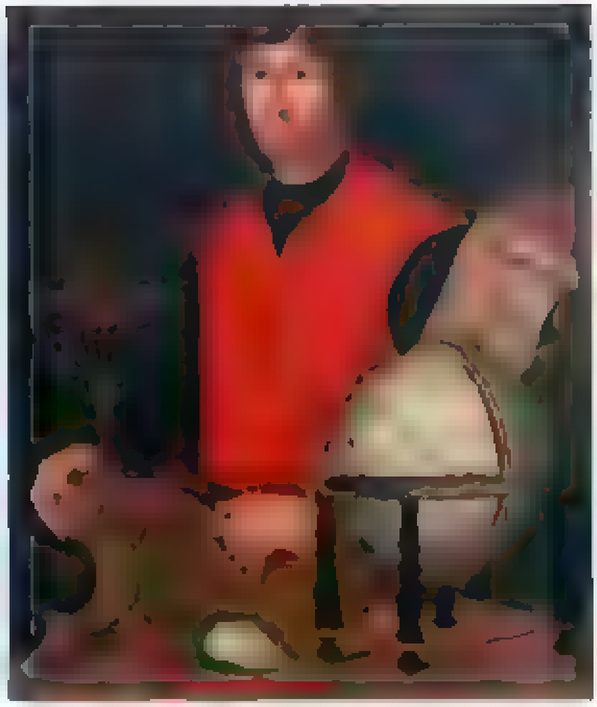


Many believe that astronomy died with the Greeks, and was brought to life again by Copernicus, the 15th century Polish astronomer who is famous for introducing the Sun-centred theory of the solar system, which marked the beginning of modern astronomy.

However, many historians now think it is not a coincidence that his models of planetary theory are mathematically identical to those prepared by Ibn al-Shatir over a century before him. It is known that Copernicus relied heavily on the comprehensive astronomical treatise by al-Battani, which included star catalogues and planetary tables.

The mathematical devices discovered by Muslims before Copernicus, referred to in modern terms as linkages of constant length vectors rotating at constant angular velocities, are exactly the same as those used by Copernicus. The only, but important, difference between the two was that their Earth was fixed in space, whereas Copernicus had it orbiting around the Sun. Copernicus also used instruments which were particular to astronomy in the East, like the parallactic ruler, which had previously only been used in Samarkand and Maragha Observatories.

Nicolaus Copernicus, 18th century



A Russian stamp issued in 1973 showing al-Biruni

any point of the globe. He also wrote, in total 150 works, including thirty-five treatises on pure astronomy, but only six have survived.

Ibn Yunus made observations for nearly thirty years from 977 using a large astrolabe nearly 1.4 metres in diameter. He recorded more than ten thousand entries of the Sun's position throughout all these decades.

'Abd al-Rahman al-Sufi was a Persian astronomer who lived during the 10th century and you can read more about him in the 'Stars' section of this chapter.

Al-Farghani was one of Caliph al-Ma'mun's astronomers, who wrote on the astrolabe explaining the mathematical theory behind the instrument and correcting the faulty geometrical constructions of the central disc that were current then. His most famous *Book on Sun Movement and Encyclopedia of Star Science* on cosmography contains thirty chapters including a description of the inhabited part of the Earth, its size, and the distances of the heavenly bodies from the Earth and their sizes.

Al-Zarqali, known as Arzachel or Azarquiel in Europe, died in 1087. He prepared the famous Toledan Tables, and also made a sophisticated astrolabe that could be used at any geographical location, called a *saphia*, and accompanied it with expansive explanatory notes.

Jabir ibn Aflah, who died in 1145, was the first to design a portable celestial sphere to measure celestial coordinates (today called a torquetum). Jabir is specially noted for his work on spherical trigonometry.

Ibn Rushd from 12th century Cordoba was known in the West as Averroes. He was one of the most famous doctors in Cordoba, but he was also an astronomer and discovered sunspots.

In the case of lunar motion, 14th century astronomer **Ibn al-Shatir** corrected Ptolemy, whose imagined Moon approached far closer to the Earth than did the actual Moon. After noting, as did other Muslim astronomers before him, the shortcomings of the Greeks planetary theory, Ibn al-Shatir said, 'I therefore asked Almighty God to give me inspiration and help me invent models that would achieve what was required, and God, may He be praised and exalted, all praise and gratitude to Him - did enable me to devise universal models for the planetary motions in longitude and latitude and all other observable features of their motions, models that were free - thank God - from the doubts surrounding previous models.'

Traces of medieval Islamic astronomy are still seen today. The words zenith, azimuth and the names of stars in the Summer Triangle, Vega, Altair, Deneb, are all of Arabic origin. Today thousands of Muslim astronomical manuscripts still remain unexamined, but the most prominent of these thousand-year-old astronomers, who spent their lives looking into the heavens, are now, at last, becoming known.

15th century Persian manuscript of Nasir al-Din al-Tusi's observatory at Merega showing astronomers at work and the teaching of astronomy including the use of an astrolabe. Also note the astrolabe hanging on the wall.

Observatories

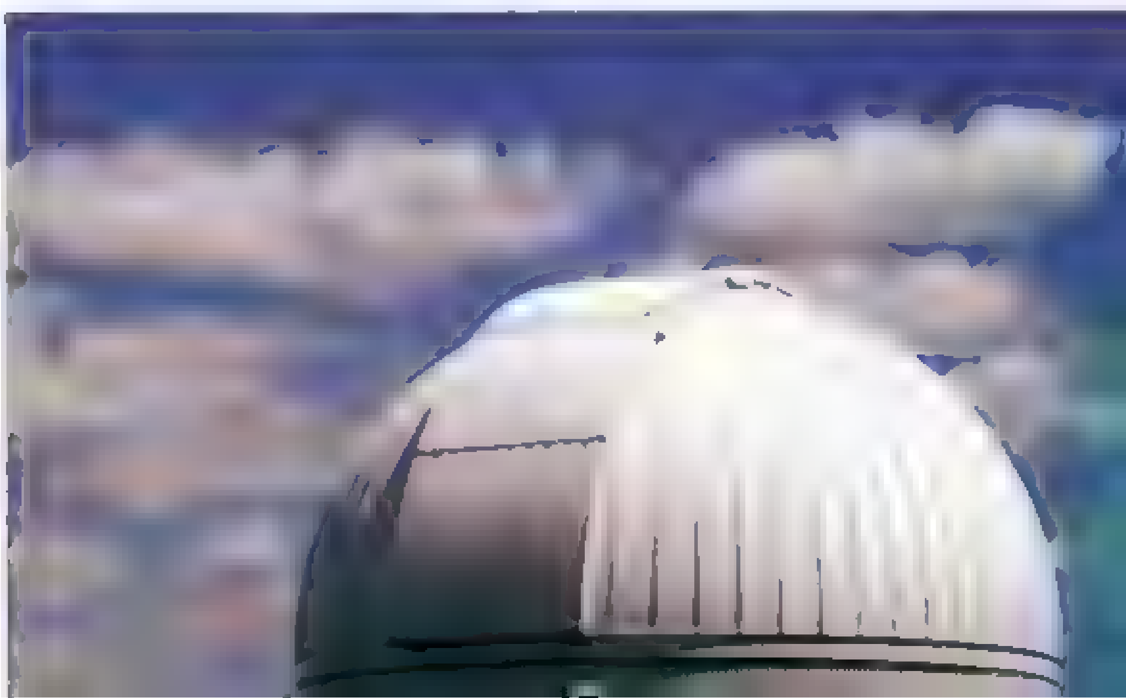
FROM THE BEGINNINGS OF HUMAN AWAKENING, people have marvelled at the amazing canopy of stars and at the movement of everything in the sky. Clearly, there was order in the heavens, and many attempts were made to identify the patterns in this order.

This had great significance for life since through these observations came the beginnings of predictive science, and now we can predict the position of the Sun in the sky, the Moon, the timing of eclipses, the changing position of the planets and the stars.

It's not that Muslims were the first to study astronomy, but they were the first to do it on a large scale, with massive instruments in observatories. Astronomical research was expensive, needing costly equipment and the cooperation of many astronomers. Good work was done previously with small-sized, portable instruments, and Ptolemy carried out his observational work with these.

There was one man, Caliph al-Ma'mun ruling from Baghdad from 813 to 833 CE, who really gave astronomy the patronage and impetus it needed to become a major science. He was the first person to set up observatories. The concept of a fixed location with large and fixed instruments, programmes of work, scientific staff made up of several astronomers and royal patronage or affiliation from the state, were all novel ideas introduced by al-Ma'mun. Nothing comparable can be found before the Muslim astronomers. Al-Ma'mun not only built the first observatory in Islam, but he arguably built the first observatory in the world or in history. Al-Ma'mun was an enlightened leader who also played a major part in setting up the House of Wisdom, one of the greatest intellectual academies in history, which you can read about in the School chapter.

The first observatory near Baghdad opened in 828 and the first German, and probably European, observatory was built in Kassel in 1558.



The earliest observatories were in the al Shammasiyah quarter of Baghdad and on Mount Qasiyun at Damascus, and these led to the emergence of fixed places for specialized and collective work. A major task of such observatories was to construct astronomical tables. These helped in the calculation of planetary positions, lunar phases, eclipses and information for calendars. They often included explanations of astronomical instruments. Al Ma'mun's observatories prepared solar and lunar tables and had a star catalogue plus some planetary observations.

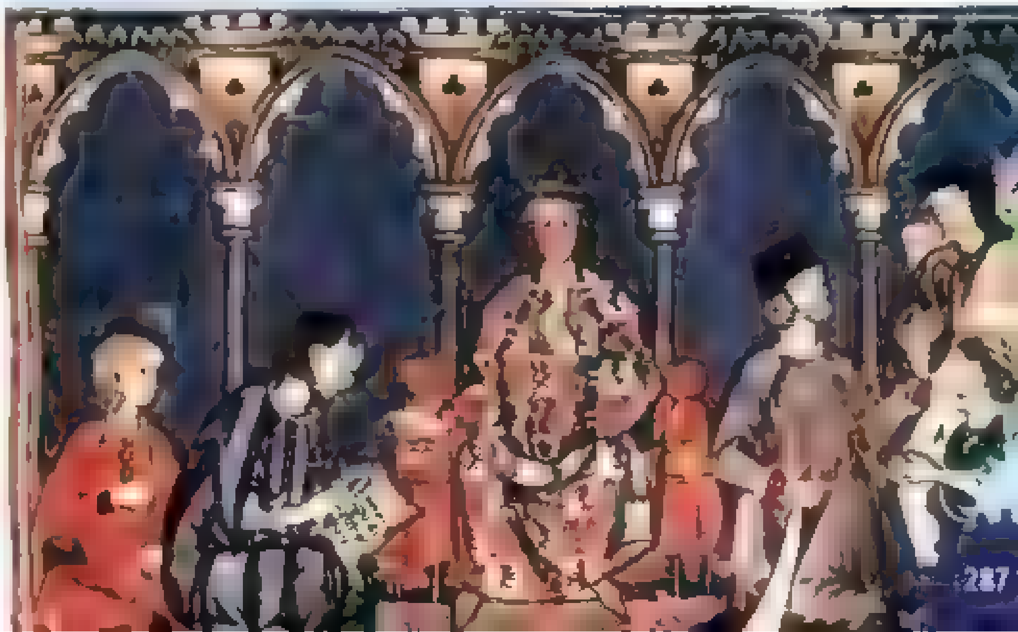
At al Shammasiyah, astronomers observed the Sun, the Moon, the planets and some fixed stars. The results of the work done here were presented in a book called the *Mumtahan Zij* or *Verified Tables* whose author is said to be Ibn Abi Mansour.

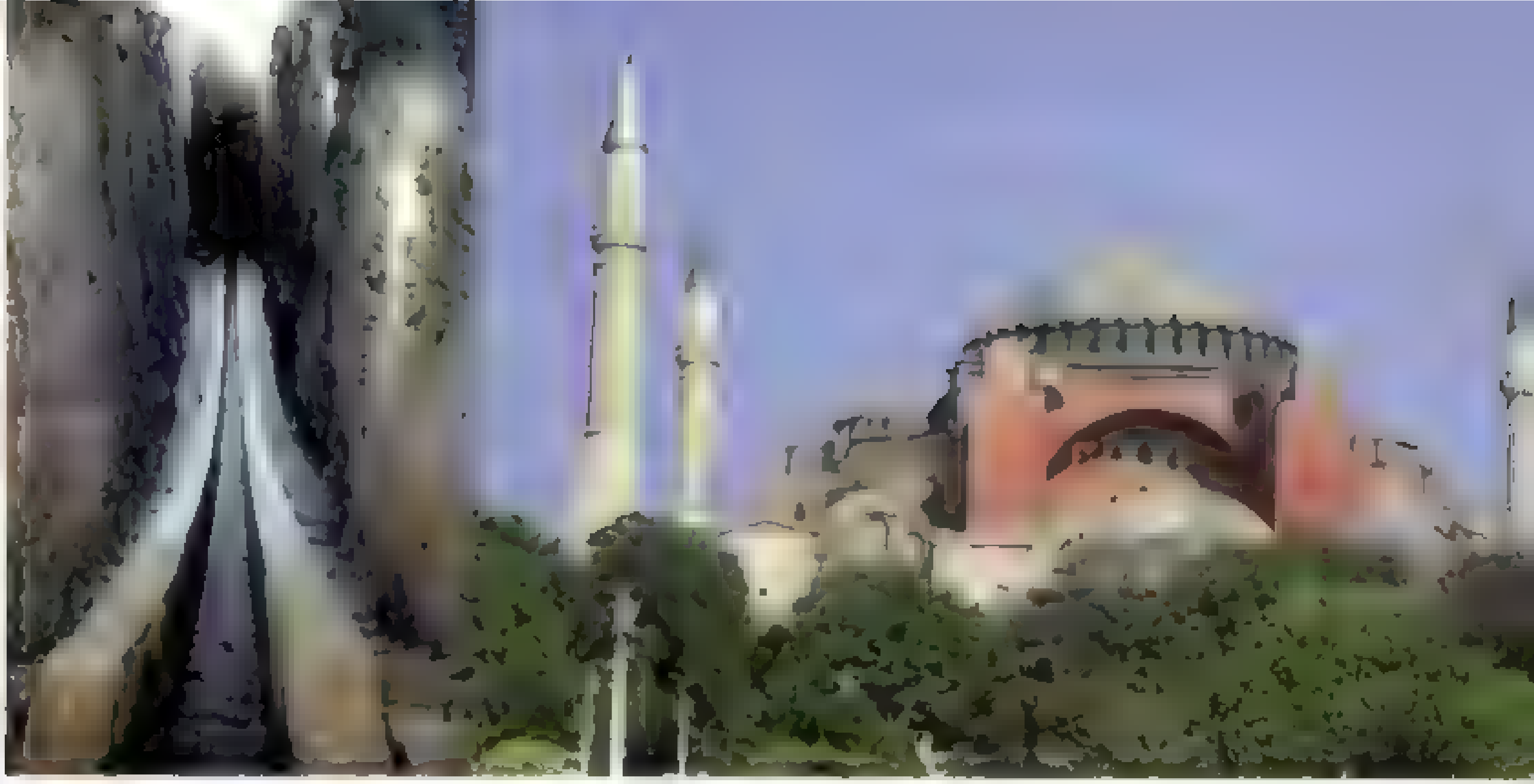
Other observatories were built all over the Muslim world, like the Maragha Observatory founded by Hulagu Khan, the Samarkand Observatory of Ulugh Beg, the Malik Shah Observatory at Isfahan, and the Tabriz Observatory of Ghazan Khan.

The Maragha Observatory was completed in 1263 in Iran to the south of Tabriz, and its foundations are still there. The main work done in Maragha was the preparation of new astronomical tables and the observatory library contained over forty thousand books. Among the eminent astronomers associated with the observatory were Nasir al-Din al-Tusi and Qutb al-Din al-Shirazi, who is credited with the discovery of the true cause of the rainbow. Nasir al-Din al-Tusi prepared the Ilkhanid Tables and the catalogue of fixed stars which remained in use for several centuries throughout the world. An astronomer from Maragha was sent to China, and the dynastic chronicles of the Yuan bear record of how he designed an instrument for observing the heavens, which was erected on the Great Wall.

Alfonso X, a Spanish king of the second half of the 13th century, tried to carry on the Islamic tradition of building observatories in western Europe, but he didn't succeed – maybe because astrology was frowned upon by the Church and the usefulness of astronomy was questioned. Four centuries later, however, the situation gradually changed and knowledge of astronomy gained depth and breadth, with Europe absorbing all that had gone on in the Islamic world. So much so that the instruments used by the famous 16th century observational astronomer Tycho Brahe were very similar to those used earlier by Muslim astronomers. His famous mural quadrant was like those developed in eastern Islam.

King Alfonso X





Left to right: Giant marble sextant inside Ulugh Beg Observatory; the radius of that meridian arc at Ulugh Beg Observatory was equal to the height of the dome of the Ayasofya Mosque in Istanbul

Ulugh Beg was the 15th century ruler of the Timurid Empire, which stretched over central and Southwest Asia. As well as being the ruling sultan, he was also an astronomer and mathematician, which led him to build a three-storey observatory for solar, lunar and planetary observations in Samarkand.

The Samarkand Observatory was a monumental building equipped with a huge meridian made of masonry, and became the symbol of the observatory as a long lasting institution. A trench about two metres wide was dug in a hill, along the line of the meridian, and in it was placed the segment of the arc of the instrument. The radius of that meridian arc was equal to the height of the dome of the Ayasofya Mosque in Istanbul, which was about fifty metres. Built for solar and planetary observations, it was equipped with the finest instruments available, including a Fakhri sextant with a radius of 40.4 metres. This was the largest astronomical instrument of its type. The main use of the sextant was to determine the basics of astronomy, such as the length of the tropical year. Other instruments included an armillary sphere and an astrolabe, which you can read about in this Universe chapter.

Ulugh Beg's work was very advanced for his time and surprisingly accurate. His calculation that the stellar year was three hundred and sixty five days, six hours, ten minutes and eight seconds long was only sixty two seconds more than the present estimation, an accuracy of 0.0002 per cent is remarkable.

Observatories were massive, with continuous observational programmes needing organization and efficiency of administration, so astronomers directed and supervised other members of the staff in their work. Later observatories are known to have had directors, treasurers, clerks librarians, and other administrative officers, as well as their staff of scientists.

Even though the main work carried out at al Ma'mun's observatories in al Shammasiyah and on Mount Qasiyun was the construction of astronomical tables, other original and epoch-making discoveries also occurred resulting, for example, in the discovery of

16th-century Turkish manuscript from the *Book of the Kings* showing Taqi al-Din and other astronomers with their sophisticated devices at the Istanbul Observatory

the movement of the solar apogee. Other remarkable discoveries can be read about in other sections of this chapter.

A magnificent but short-lived observatory was built in the 16th century for Taqi al-Din who was one of the most notable scientists in the Muslim world. He had convinced the new sultan, Murad III, to fund the building of the Istanbul observatory, and it was completed in 1577.

With two outstanding buildings, built high on a hill overlooking the European section of Istanbul, it had an unobstructed view of the night sky. Like a modern observatory today, the main building held the library and housed the technical staff, while the smaller building contained an impressive collection of instruments built by Taqi al-Din himself. This included a giant armillary sphere and a mechanical clock for measuring the position and speed of the planets.

Taqi al-Din wanted to update the old astronomical tables describing the motion of the planets, Sun and Moon. However, his observatory was destroyed by the sultan because of numerous socio-political reasons linked with the Black Death and internal palace rivalry. Despite this, Taqi al-Din left an enormous legacy of books on astronomy, mathematics and engineering.

As well as building the first observatories, Muslims had among them a pioneering 9th-century Cordoban who built a planetarium. Unlike an observatory where the heavens are studied, a planetarium is a room where images of the stars, planets and other celestial bodies are projected. Ibn Firnas, better known for his experiments in flight, made a planetarium in one room of his house out of glass, showing the night sky as it was then. This very much resembled today's planetariums, and he even added artificial thunder noise and lightning.

Astronomical Instruments

WHAT MUSLIMS REALLY PIONEERED were huge observational instruments designed and built to study the heavens, and by using large-sized instruments they reduced the percentage error in their measurements. The observatory at Damascus had a twenty-foot quadrant and a fifty-six foot sextant which is the same as about ten cars end to end. The Maragha Observatory also had many large instruments including quadrants, armillary spheres and astrolabes.

Other instruments included celestial globes, quadrants and sextants. (You can read about astrolabes and armillary spheres in more detail in separate sections in this Universe chapter.) All these instruments used in observatories had to be accurate because the observatories' reputations depended on the results they produced.

A 13th-century brass celestial globe from Maragha, Iran made by Muhammad ibn Hilal.

Jabir ibn Aflah from Spain, who died in 1145 CE, was the first to design a portable celestial sphere to measure celestial coordinates (called a torquetum), but it was the 10th-century astronomer al-Battani, working in Iraq, who was the main astronomer writing on celestial globes. He didn't use his globes as observational instruments, instead he wanted to precisely record celestial data. He described one that was suspended from five rings which he called *al-baydah* or 'the egg,' giving detailed directions on how to plot the coordinates of each of one thousand and-twenty-two stars. The treatise is quite influential as it gave details of how stars should be marked onto the globe. This meant that instrument makers around that time could produce a globe to this particular standard.

Al-Battani's treatise was very different from the pre-Ptolemaic design of a celestial globe, which used five parallel equatorial rings and constellation outlines. Instead, al-Battani had a more precise method of charting the stars using the ecliptic and equator, and dividing them into small divisions. This method then allowed the stars to be given exact coordinates, and of course this increased precision.

The Muslims were skilled tool and instrument makers. An important maker of celestial globes was 'Abd al-Rahman al-Sufi who was born in 903. He wrote a treatise on the design of constellation images for celestial globe makers that had great influence in the Muslim world as well as in Europe. His other treatises included one on the astrolabe and one on how to use celestial globes.

Many globes were constructed up to the 16th century, and many still exist today, but none prior to the 11th century have survived.

There are many scholars who wrote about astronomical instruments and here are just a few of them: Abu Bakr ibn al-Sarraj al-Hamawi who died in Syria in 1329 wrote several books on scientific instruments and

Two of the most influential astronomers in the 16th century were Taqi al Din from Istanbul, and Tycho Brahe, who built an observatory under the sponsorship of King Frederic II of Denmark in 1576. This was equipped with the best possible and refined instruments of his time, helping him make accurate observations and aiding the discoveries of Kepler, who was Tycho Brahe's assistant.

Recent research has shown that there is an exact identity between most of the instruments of Tycho Brahe's and Taqi al Din's observatories (you can read more about this in the 'Observatories' section), but both men were not satisfied with the instruments of the previous astronomers. They had newly discovered instruments to use, such as the sextant, the wooden quadrant and the astronomical clock.

Taqi al Din's sextant was called mushabbaha bil manatiq or 'replication by areas' and was made from three ruled scales. Two of the scales formed the edges of the three-edged sextant. At the end was an arc which was attached to one of the rules and was used to determine the distances between the stars. The sextants of these two men should be considered among the finest achievements of the 16th century.

Mural quadrant by Tycho Brahe 1598

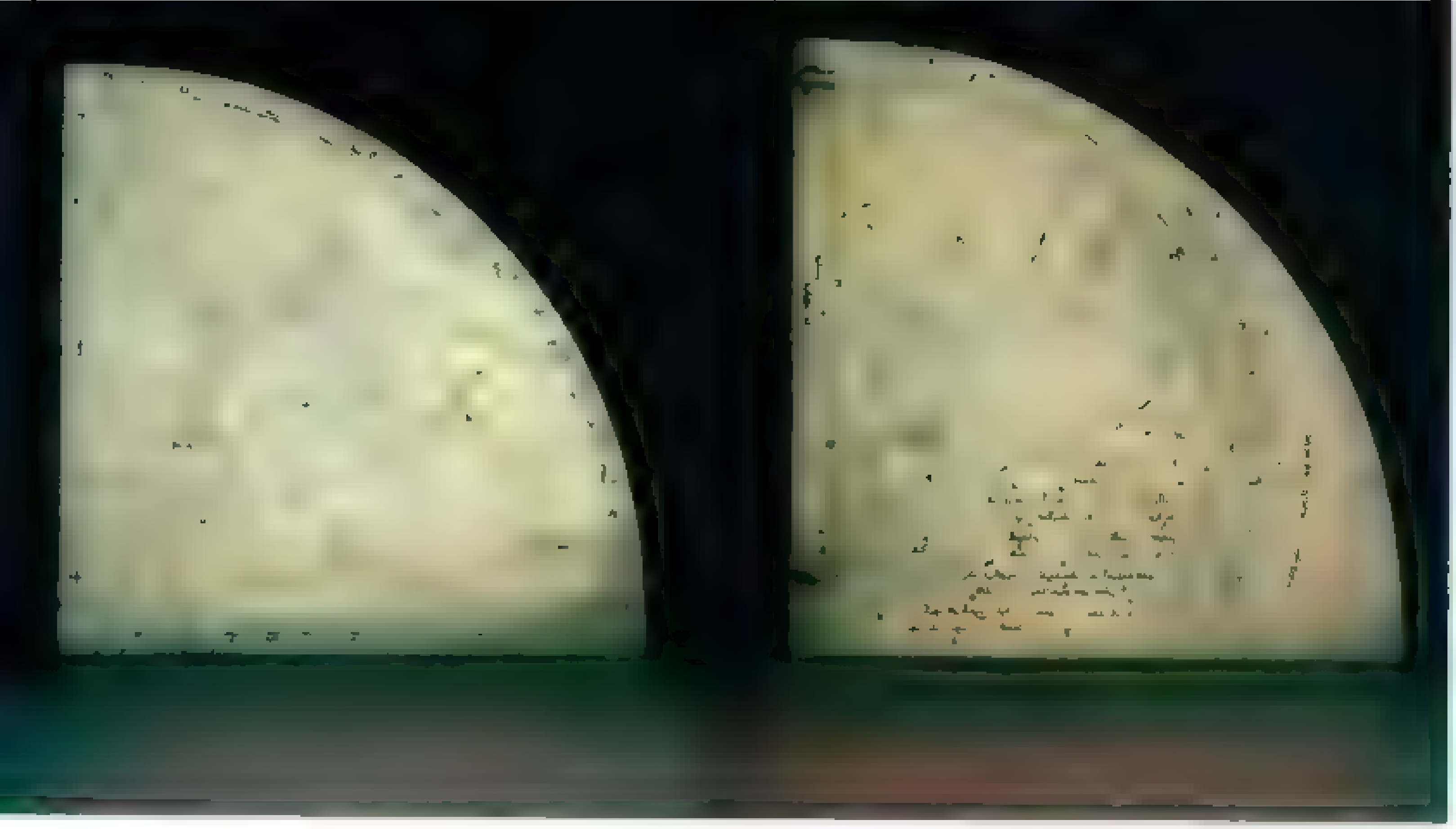
geometrical problems, while also inventing a quadrant called *al-muqantarat al-yusra*. He dedicated much time to writing about the quadrant and his books include *Treatise on Operations with the Hidden Quadrant* and an opulent sounding work called *Rare Pearls on Operations with the Circle for Finding Sines*. Despite his accomplishments, especially in the field of scientific instrument making, there has been no single study of him and his works.

Ahmad al-Halabi, who died in 1455, was an astronomer from Aleppo in Syria. He wrote on instruments in *Aims of Pupils on Operations with the Astrolabe Quadrant*.

His contemporary 'Izz al-Din al-Wafa'i was primarily a mathematician, *muezzin* and *muwaqqit*, or timekeeper, at the Umayyad Mosque in Cairo, and he wrote a staggering number of forty treatises on mathematics including arithmetic, operations with the sexagesimal ratio, and a large number of works dealing with instruments. Amongst these was *Brilliant Stars on Operations with the Almucantar Quadrant*.

Sextants and quadrants were used to measure the altitude of celestial objects above the horizon. The quadrant, in particular, was used extensively by Islamic astronomers, who had greatly improved on its design.

Muslim astronomers invented quite a few quadrants. There was the sine quadrant, used for solving trigonometric problems



Reverse and obverse of a 14th-century astrolabe quadrant made by Ibn Masar al-Mizzi, the official time-keeper of the Great Umayyad Mosque in Damascus, Syria

and developed in 9th-century Baghdad; the universal quadrant, used for solving astronomical problems for any latitude and developed in 14th-century Syria; the horary quadrant, used for finding the time with the Sun; and the astrolabe/almucantar quadrant, a quadrant developed from the astrolabe. Most of these were used in conjunction with the astrolabe.

To measure the obliquity of the ecliptic, the angle between the plane of the Earth's equator and the plane of the Sun's ecliptic, al-Khujandi in 994 used a device that he claimed was his own invention. It was called the Fakhri sextant because his patron was Fakhr al-Dawla, the Buwayhid ruler of Isfahan. Al-Khujandi claimed to have vastly improved on similar past instruments, because these could only be read in degrees and minutes while with his instrument, seconds could also be read.

This instrument incorporated a sixty degree arc on a wall aligned along a meridian, the North-South line. Al-Khujandi's instrument was larger than previous such instruments; it had a radius of about twenty metres.

Taqi al-Din preferred to use a fifth type of quadrant called a mural quadrant rather than al-Khujandi's Fakhri sextant. This mural quadrant had two graduated brass arcs with a total radius of six metres only, a staggering twenty metres smaller than al-Khujandi's, which were placed on a wall along a meridian. In order to take a reading, the astronomers aligned the rod or cord on the quadrant with the celestial body, a moon or the Sun, and read off the angle from the mural quadrant.

These enormous astronomical observation instruments have been significantly down-sized in modern times, but their technology laid the foundations for the modern day sextant, a portable instrument, and, before Global Positioning Systems existed, they were the main navigational instruments.

Taqi al-Din's *mushabbahah bil manatiq* or sextant. This is a picture from a manuscript depicting Taqi al-Din's observatory in 1580 in Istanbul. The name of this manuscript is *Alat-i Rasadiya li Zij-i Shahinshahiya*, meaning 'Astronomical Observational Instruments,' and this picture zooms in on scientists operating a sextant

Astrolabe

SINCE ISLAM BEGAN, the *muezzin* has called the faithful to prayer five times a day. These prayer times are astronomically determined, changing from day to day, so it was vital to know exactly when they were, and before modern technology, Muslims developed an extraordinarily accurate device called the astrolabe to help them do this.

The astrolabe is described by Dr Williams, an American astrophysicist, as 'the most important astronomical calculating device before the invention of digital computers and the most important astronomical observational device before the invention of the telescope.'

The earliest origins of the astrolabe are unknown. We know Theon of Alexandria wrote on the astrolabe in the 4th century CE, and the earliest preserved Greek treatise on the subject is from the 6th century. The origin of the word astrolabe is in the Arabic word *asturlab*, which is said to be a transliteration of a Greek word. Whatever its origins, the instrument was fully developed, and its uses expanded, by Muslim astronomers because they needed to determine prayer times and the direction of Mecca. In the Islamic world, astrolabes remained popular until 1800.

New treatises on the astrolabe were produced, the earliest by MashaAllah 'Ali ibn 'Isa, and al-Khwarizmi in the early 9th century, while the earliest surviving Islamic instrument dates from the middle of the 10th century, built by an apprentice to 'Ali ibn 'Isa in Baghdad. With the Muslim presence in Spain from the 8th century, Islamic learning, including that on the astrolabe, seeped into western Europe, so that the earliest surviving Christian or western instruments are from the 13th century onwards.

Quite a few types were made, and the most popular was the planispheric astrolabe, where the celestial sphere was projected onto the plane of the equator.

This working astrolabe, created by Mohamed Zakariya, requires a wealth of knowledge to build. Using ancient techniques, such an astrolabe can take from three to six months to complete as it requires extensive geometrical calculations and precision engraving for it to work accurately.

Astrolabes were 2-D models of the heavens, showing how the sky looked at a specific place at a given time. This was done by drawing the sky on the face of the astrolabe and marking it so that positions in the sky were easy to find. Some astrolabes were small, palm-sized and portable; others were huge, with diameters of a few metres.

They were the astronomical and analogue computers of their time, solving problems relating to the position of celestial bodies, like the Sun and stars, and time. In effect, they were the pocket watches of medieval astronomers. They could take altitude measurements of the Sun or stars to tell the time during the day or night, or find the time of a celestial event such as sunrise, sunset or culmination of a star. This was made possible by the use of ingenious tables printed on the back of the astrolabe. These tables could contain information about curves for time conversions, a calendar for converting the day of the month to the Sun's position on the ecliptic, trigonometric scales and a graduation of 360 degrees.

They were based upon the model of the Earth being at the centre of a spherical universe, with an imaginary observer positioned at a particular latitude and time outside this sphere and looking down upon it. On the astrolabe that the astronomer was holding, the major stars in the sky were represented on a pierced metal plate, which was set into a larger flat circular holder called a mater. Because the plate with the stars was pierced, the astronomer could see through it onto another plate beneath, which would have lines representing his particular geographical location. Several plates would be included in an astrolabe so that the astronomer could move about from one latitude to the other. After using the sighting device on the back of the plate to determine the altitude of a star or the Sun, the astronomer would then rotate the pierced star map over the plate for his location so as to coincide with the sky at that time. Then all sorts of calculations could be made. For the more accurate coordinates of celestial bodies necessary for detailed astronomical tables, astrolabes had to be used in conjunction with other instruments, such as large quadrants and observatories' armillary spheres.

Astrolabes worked with fixed and rotating parts. The mater was a hollow disc holding the

Astrolabes were the astronomical and analogue computers of their time, solving problems relating to the position of celestial bodies.

[illegible] century astrolabe and its parts. This astrolabe was made by Ibn [illegible] [illegible].

Chaucer, author of the Canterbury Tales *also wrote a* Treatise on the Astrolabe *for his ten year-old son, Lewis, in 1387. Here is what he said about it.*

'Little Lewis my son, I have considered your anxious and special request to learn the Treatise of the Astrolabe ... therefore have I given you an astrolabe for our horizon, constructed for the latitude of Oxford. And with this little treatise, I propose to teach you some conclusions pertaining to the same instrument. I say some conclusions, for three reasons. The first is this: you can be sure that all the conclusions that have been found, or possibly might be found in so noble an instrument as an astrolabe, are not known perfectly to any mortal man in this region, as I suppose'

rete (the pierced star map) and the rotating plates were placed on top of each other. On the back of the mater was the alidade (the sighting device) and various trigonometric tables. In this respect the astrolabe was a graphical computer

Islamic makers attempted to develop different types of astrolabes, like the spherical astrolabe and the linear astrolabe, none of which were widely adopted. Mariner's astrolabes were developed in the late 15th and 16th centuries by the Portuguese

A highly sophisticated form of the astrolabe, the universal astrolabe, was developed in Toledo in the 11th century, and it revolutionized star mapping. Two individuals, Ali ibn Khalaf al Shakkaz, an apothecary or herbalist, and al Zarqali, an astronomer, were important in this new development. The universal astrolabe was a major breakthrough because it could be used at any location. Ordinary astrolabes needed different latitude plates if they were moved, because they were designed for a certain place, so they were latitude dependent

An important aspect of the universal astrolabe was that its stereographic projection used the vernal or autumnal equinox as the centre of projection onto the plane of the solstitial colure

Dr Julio Samso of Barcelona University, talking with Rageh Omar on the BBC's *An Islamic History of Europe*, said that Muslims used new computing devices and '... the universal astrolabe was designed that had applications that were impossible with the standard astrolabe'

Astrolabes, and in particular universal astrolabes, really were the cutting edge of technology, used and developed prolifically by Muslim astronomers who were intrigued and fascinated by the heavens. It was through these hard working scholars that the astrolabe made it into Europe, where modern astronomy was born.

Armillary Sphere

IN AN ATTEMPT TO MAKE PREDICTIONS of the movement of heavenly bodies easier, people from many great civilizations built different kinds of models to represent in physical form what they saw in the sky. These models were built based on the idea of the Earth having a sphere of stars surrounding it. One of these models was the armillary sphere.

Armillary spheres modelled the heavens and planetary motions, showing medieval Muslim astronomers how the universe worked in 3D, and they came very close to the model we know today. They were not solid globes, but made up of concentric rings, with the Earth at the centre, and the bodies that surrounded it.

The construction and use of armillary sphere started in the 8th century, and they were first written about in Baghdad in the treatise of *The Instrument with the Rings* by al-Fazari. But it was in the 10th century that they reached an advanced level of sophistication, and they were produced in two main varieties.

Demonstrational armillary spheres concentrated on the Earth, and a tiny model of the globe was surrounded by the rings of ecliptic (the apparent path of the Sun around the Earth), the circle of the equator, tropics and polar circles. These were all held in place by a graduated meridian ring, and pivoted about the equatorial axis. The Moon, planets and stars didn't appear in these models, but they did give the relative motions of bodies about Earth.

The second type was the observational armillary sphere, which was different because it didn't have the Earth globe in the centre, and had mounted sighting devices on the rings. These spheres were larger, and were tools used to determine coordinates and other values.

There were many Muslim astronomers who wrote about observational armillary spheres, like Jabir ibn Aflah from Seville, known in the West as Geber (not to be confused with Geber the chemist), from the mid-12th century. They referred to the descriptive work of Ptolemy's *Syntaxis*, written in the 2nd century, known as *Almagest* in the Islamic world.

Armillary spheres to study the Earth and skies were found in observatories, such as the 13th-century Maragha Observatory, the 15th century Samarkand Observatory, and the 16th century observatory at Istanbul. You can read more about the extraordinary work carried out by observatories in this chapter.

Right: A demonstrational armillary sphere in an engraving from the *Jihannuma* or *Universal Geography*, Istanbul, 1732, a reprint of the original *Jihannuma* written in the 17th century by the famous scholar, Katib Celebi (Hajji Khalifa).

This 16th century manuscript shows astronomers lining up various parts of the armillary sphere with specific stars so that they could produce flat charts of the heavens which were then plotted and made into astrolabes. These would then guide people, using the stars. The central pendulum is used here to trace the trajectories of the stars and planets on the flat ground so as to create these charts.

Signs for Wise People

THE QURAN OFTEN REFERS to various natural phenomena in a very inspiring manner, and challenged mankind to ponder these phenomena using reason.

For example: 2:164 *Verily, in the creation of the heavens and of the earth, and the succession of night and day: and in the ships that speed through the sea with what is useful to Man: and in the waters which God sends down from the sky, giving life thereby to the earth after it had, been lifeless, and causing all manner of living creatures to multiply thereon: and in the change of the winds, and the clouds that run their appointed courses between sky and earth: [in all this] there are messages indeed for people who use their reason.*

Astronomical phenomena are frequently cited in the Quran and often put in the context of their use to mankind as in time keeping and navigation. It talks about precise orbits and courses, and thus passing the message that behind these phenomena lies a coherent system that they are invited to explore. Here are some examples:

6.97: *(God) is the One Who has set out for you the stars, that you may guide yourselves by them through the darkness of the land and of the sea We have detailed the signs for people who know.*

16.12: *For you (God) subjected the night and the day, the sun and the moon, the stars are in subjection to His Command. Verily in this are signs for people who are wise.*

21. 33: *(God is) the One Who created the night, the day, the sun and the moon. Each one is travelling in an orbit with its own motion*

55:5 *The sun and the moon follow courses (exactly) computed.*

Verses like those cited above formed an intellectual challenge to people to build the required knowledge to explore a universe abundant with God's wonders.

Not only that, but in one verse, humans are even encouraged to make their way out of the earth in order to explore space, but with a warning that this should only be done when they have enough power and control.

55:33 O *you assembly of Jinns and Humans! If it be you can pass beyond the zones of the heavens and the earth, pass you! not without authority(power) shall you be able to pass!*

Typical Arabic verses of the Quran

The Moon

On 21 July 1969, Apollo 11 landed on the lunar surface, and Neil Armstrong became the first man on the Moon. However, long before Armstrong made his first lunar step and uttered his now famous line, a number of great Muslims became associated with Earth's closest astronomical neighbour.

For Muslims the Moon is incredibly important because the calendar that is used [illegible] is determined by the cycle of the Moon. A problem they faced was that the approximate 29.5 days of a lunar month were not in line with the 365 days of a solar year: twelve lunar months only add up to only 354 days.

The Christians and Jews had confronted the same problem and they had adopted a scheme based on a discovery made in about 432 BCE by the Athenian astronomer Meton. He developed the Metonic cycle of nineteen years. This was made of twelve years of twelve lunar months and seven years of thirteen lunar months. Periodically a thirteenth month was added to keep the calendar dates in step with the seasons.

The Muslims wanted to use this cycle but [illegible] rulers sometimes added a thirteenth month when it suited their own interests, so the second caliph, Umar ibn al Khattab, who reigned for ten years from 634 CE, introduced the *hegira* calendar that is still used in Islamic countries today.

This strictly follows a lunar cycle. The *hegira* year is about eleven days shorter than the solar year, and holy months such as *Ramadan*, the month of fasting, move [illegible] the seasons. [illegible] *Ramadan* [illegible] days earlier than the last and the month of fasting falls on the same date only around every thirty solar years.

Ramadan and the other Islamic months also begin when the crescent Moon is sighted, so

[illegible] of the Moon [illegible] to determine the Muslim [illegible] the *Hijri* calendar

no one knows exactly when *Ramadan* will start until this crescent Moon appears in the night sky.

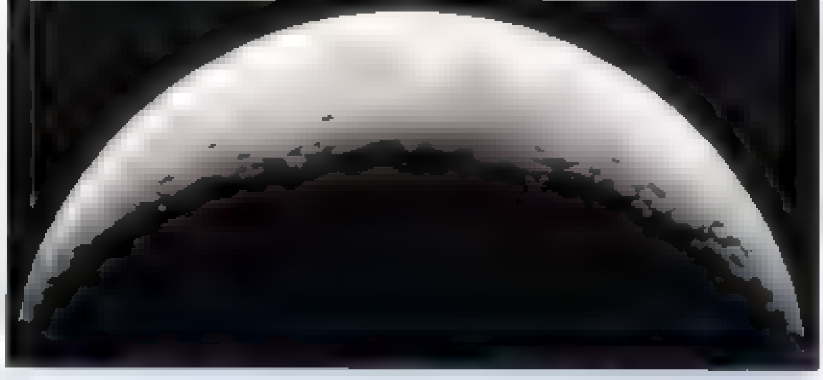
Predicting just when the crescent Moon would become visible was a special challenge to Muslim mathematical astronomers. Although Ptolemy's theory about the Moon's movements was accurate near the time of the new Moon, the invisible Moon, it only looked at the lunar path as part of the ecliptic or the Sun's path on the Moon.

Muslims realized that to predict the sighting of the crescent Moon, its movement with respect to the horizon had to be studied, and this problem demanded fairly sophisticated spherical geometry, or geometry that deals with shapes on the surface of the sphere. It was al-Kindi, working in Baghdad in the 9th century, who was the first to develop spherical geometry, which he used extensively in his astronomical works.

Spherical geometry was also needed when Muslims were finding the *Qibla*, the direction of Mecca, which they prayed toward and which their mosques faced, and it was al-Biruni who worked this out from any location on the globe. Al-Biruni was interested in everything, literally, and sometimes he is referred to as the Leonardo da Vinci of his day. Concerning the Moon, he described the eclipse of 24 May 997, when he was in Kath, in today's Uzbekistan. This event was also visible in Baghdad and he arranged with Abu al-Wafa al-Buzjani, a fellow astronomer, that the latter would observe it there. When they compared their timings, they were able to calculate the difference in longitude between the cities.

So moon watching and recording was a serious business. Back then, as now, the Moon was a constant source of fascination since knowing the order of its movements supported the idea that there was order in the heavens too. And these observations produced the structure for the Muslim calendar that has been used for over one thousand four hundred *hegira* years.

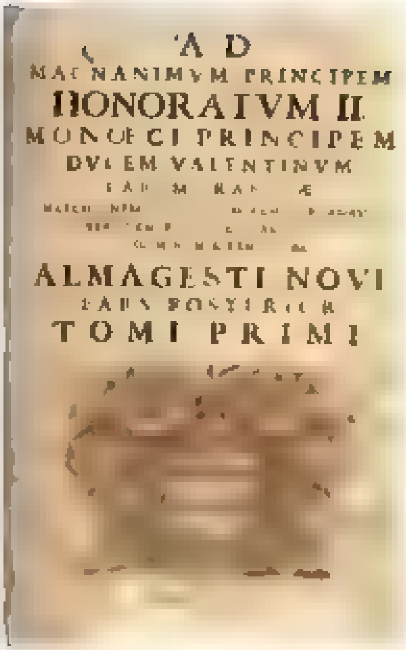
To read more about Muslim contributions to the actual physical Moon, read the next section on "Lunar Formations."



A Muslim astronomer, who lived in Cairo and observed at Baghdad in 975 CE, discovered the third inequality of the Moon's motion called the Moon's variation. Ptolemy knew about the first and second. He bore the formidable name of Abu al-Wafa al-Bouzjani.

In Europe, this third inequality of motion, that it moves quickest when it is new or full, and slowest in the first and third quarters, was rediscovered by Tycho Brahe six centuries later in about 1580.

A painting from an early 16th century Persian manuscript of [illegible] by al-Qazwini



Almagestum Novum, 1651

Lunar Formations

WHEN VIEWED WITH THE NAKED EYE, the surface of the Moon appears unevenly bright, with dark and light patches. These features are called 'lunar formations.'

In 1651 Joannes Baptista Riccioli, a Jesuit professor of astronomy and philosophy in Bologna, Italy, compiled a comprehensive work on astronomy, called *Almagestum Novum*, with a complete map of the Moon. He named the lunar formations after distinguished astronomers of the Middle Ages. Ten were given the names of Muslim astronomers and mathematicians.

These names were finally agreed upon at a conference of the International Astronomical Union in 1935. Of the 672 lunar formations, thirteen were given the names of major Muslim astronomers, and since then more have been added. Some of these names include:

Messala is a plain in the 13th section of the Moon named after Masha'Allah, who was active in 809. He was a Jew of Egypt who embraced Islam during the time of the Abbasid caliph, al-Mansur. Two of his books on astronomy were translated into Latin in the 16th century as *De Scientia Motus Orbis* and *De compositione et utilitate astrolabii*.

Almanon is a crater in the 9th section named after Caliph al-Ma'mun, the son of Harun al-Rashid, famous from *The Thousand and One Nights*. In 829, al-Ma'mun built an observatory in Baghdad. In his academy, *Bayt al-Hikmah*, the House of Wisdom, the greatest scientists and philosophers of his age carried out their researches.

Alfraganus is a crater in the 2nd section named after al-Farghani, who died around 861. He was one of al-Ma'mun's team of researchers into astronomy. His most famous book was the *Book of the Summary of Astronomy*, and this was the main influence for the Italian Dante.

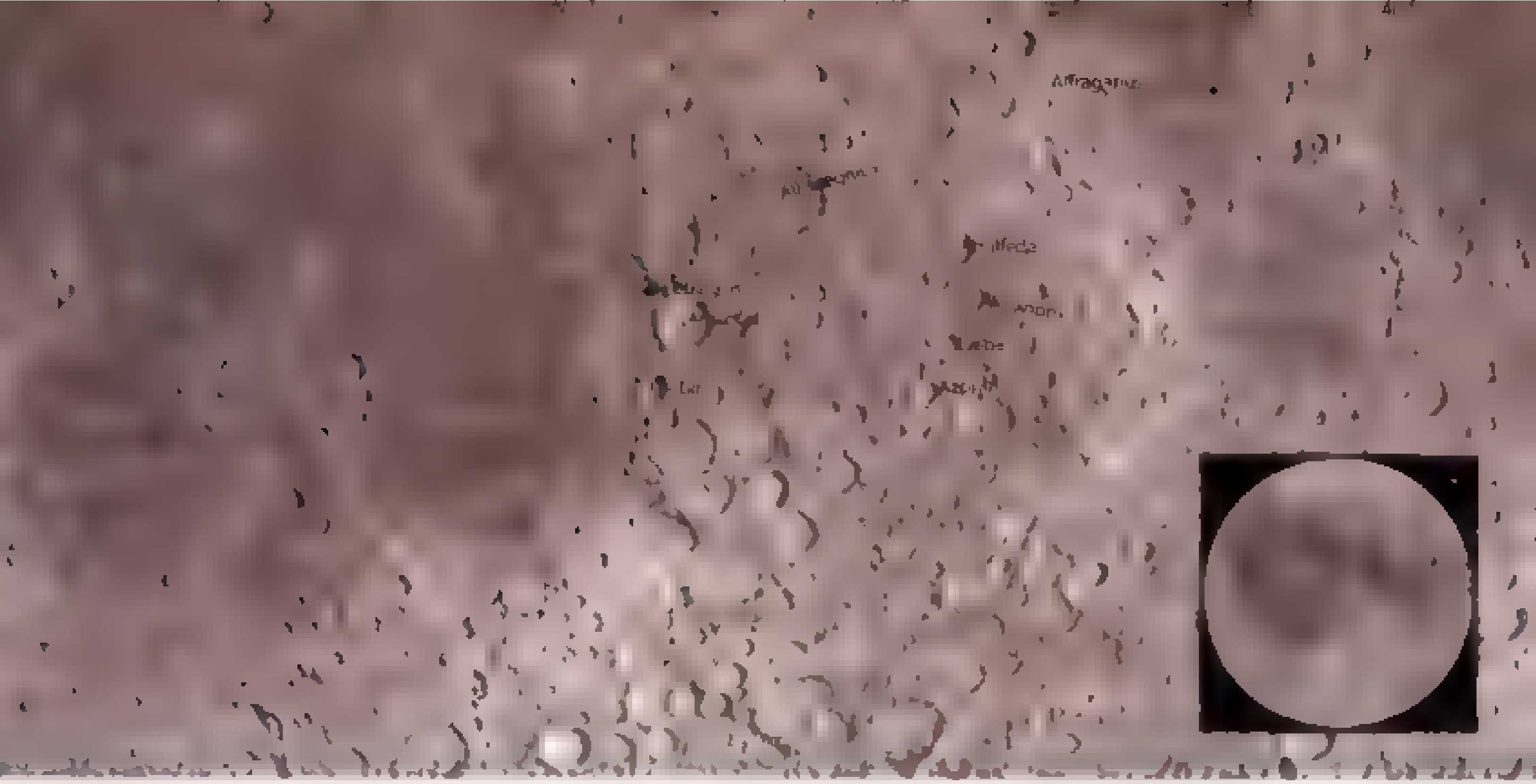
Albategnius is a plain in the 1st section named after al-Battani who was born in 858. He determined many astronomical measurements with great accuracy.

Thebit is a prominent circular plain in the 8th section named after Thabit ibn Qurra, who died in Baghdad in 901. He translated into Arabic a large number of Greek and Syrian works on science. He also made major contributions of his own to pure mathematics.

Azophi is a mountainous ring in the 9th section named after the 10th-century 'Abd al-Rahman al-Sufi. He was one of the most outstanding practical astronomers of the Middle Ages. Al-Sufi's illustrated book *The Book of Fixed Stars* was a masterpiece on stellar astronomy.

Alhazen is a ring-shaped plain in the 12th section named after Abu Ali al-Hasan Ibn al-Haitham, usually known simply as ibn al-Haitham. He was born in Basra around 965 and spent most of his working life in Egypt, where he died in 1039. He composed almost a hundred works, of which about fifty-five are preserved today, all concerned with mathematics, astronomy, and optics. He was one of the foremost investigators of optics in the world, and his *Book of Optics* had an enormous influence on European science.

Arzachel is a plain in the 8th section named after al-Zarqali, who died in 1100. He worked



A lunar map showing the formations named after eminent Muslim scholars

in Muslim Spain in collaboration with other Muslim and Jewish astronomers and prepared the famous Toledan Tables. His work may have influenced that of Copernicus.

Geber is a circular, flat plain in the 9th section named after Jabir ibn Aflah, who died in 1145. He was a Spanish Arab who was the first to design a portable celestial sphere to measure celestial coordinates, today called a torquetum.

Nasireddin is a crater thirty miles in diameter named after Nasir al-Din al-Tusi, who was born in 1201. He was a minister to Hulagu Khan, Ilkhanid ruler of Persia from 1256 to 1265. He was put in charge of the observatory installed at Maraghah by Hulagu, preparing the Ilkhanid Tables and the catalogue of fixed stars, which remained in use for several centuries throughout the world, from China to western Europe.

Alpetragius is a crater in the 8th section named after Nur al-Din ibn Ishaq al-Bitruji, who was born in Morocco, lived in Ishbiliah (Seville), and died around 1204. He worked hard, unsuccessfully, at modifying Ptolemy's system of planetary motions. Al-Bitruji's book *On Astronomy* was popular in 13th-century Europe in its Latin translation.

Abulfeda is a circular plain in the 9th section named after Abu al-Fida', who was born in 1273 in Syria. He was the last Muslim geographer and astronomer trained and nurtured on the traditions established by Caliph al-Ma'mun. He was also a great historian, the most famous of his works being *Survey of Countries*.

Ulugh Beigh is a prominent elliptical ring in the 18th section named after Ulugh Beg, who was born in 1394 and founded, in 1420, a magnificent observatory in Samarkand that was equipped with excellent and accurate astronomical instruments. His most commendable and enduring work was a new catalogue of stars.

So when you glance at the Moon tonight remember all those individuals who have been immortalized in craters, plains and elliptical rings, people who have brought greater understanding and knowledge into our lives.

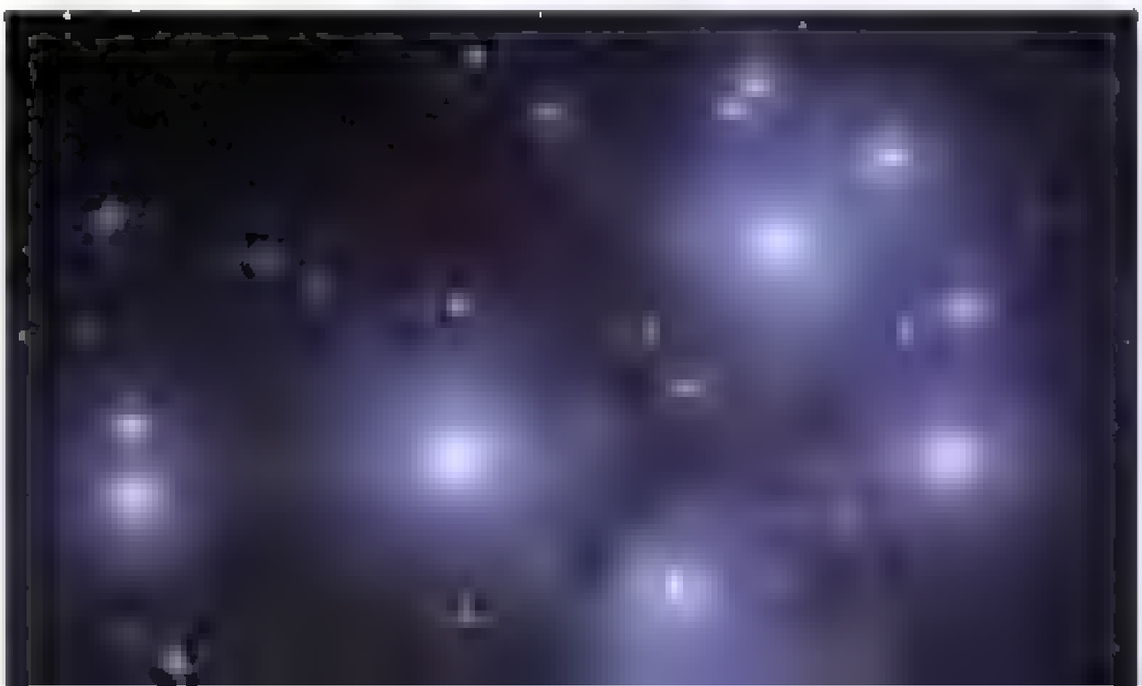
Stars

WITH THE RISE OF OBSERVATORIES and a greater interest in the night sky, Muslim astronomers from the 9th century onwards were fascinated with the night sky and carried out substantial work on stars and constellations. These included 'Abd al-Rahman al-Sufi, a Persian astronomer who lived during the 10th century; he was a real star gazer and in 964 described the Andromeda galaxy, our closest neighbour, calling it 'little cloud.' This was the first record of a star system outside our own galaxy. He set out his results constellation by constellation, discussing the stars' positions, sizes and colours, and for each constellation he gave two drawings, one from the outside of a celestial globe and one from the inside. He also wrote on the astrolabe and its thousand or so uses.

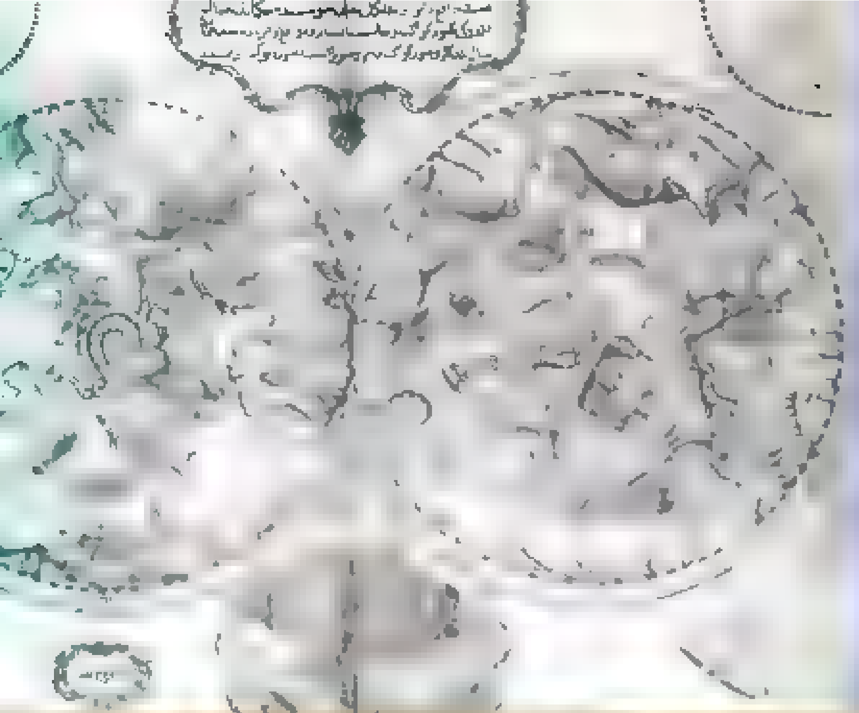
The result of this hard work was the recording of many stars and constellations, which are still known by their original Arabic names. In fact, they gave names and assigned magnitudes to 1022 in all. Today over 165 stars still have names that reflect the foregoing Arabic names, like Aldebaran, meaning 'follower' of the Pleiades, and Altair, 'the Flying Eagle.'

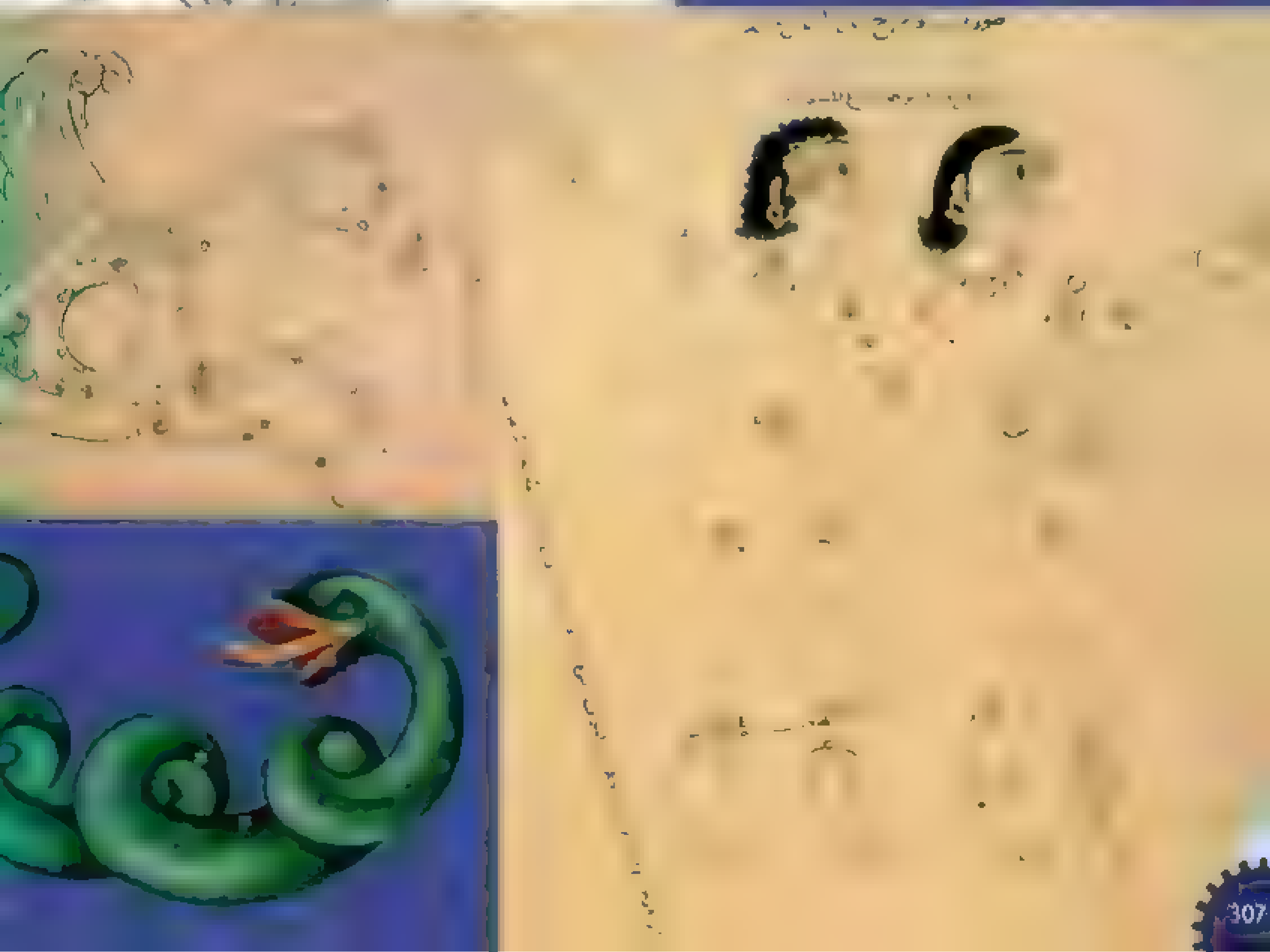
Muslims also devised star maps and astronomical tables, and both of these would be used in Europe and the East for centuries to come. Maps of the heavens also appeared as art, like on the dome of a small house at Qusayr Amra, a Jordanian palace built in the 8th century, which has a unique hemispherical celestial map. The surviving fragments of the fresco show parts of thirty-seven constellations and four hundred stars.

The Pleiades star group



Clockwise from top: ... Manual of cosmography in Turkish by Mustafa ibn Abdullah; the constellation Cepheus; [illegible] Pegasus [illegible]





Flight

IT'S INCREDIBLE THAT TODAY men and women rocket into space in metal cylinders, exploring the galaxies and bringing home rocks from Mars and the Moon. This concept of flight has fascinated and challenged humans for thousands of years.

The ancient Egyptians left behind many paintings demonstrating their desire to fly, depicting pharaohs soaring with wings. The Chinese and the Greeks had mythical stories and legends about flying, as did the Sassanians. Their most popular story is the one recounted by al-Firdawsi in his *Book of Kings*, written around 1000 CE. This says a certain King Kai Kawus was tempted by evil spirits to invade heaven with the help of a flying craft that was a throne, attached to whose corners were four long poles pointing upward. Pieces of meat were placed at the top of each pole and ravenous eagles were chained to the feet of the throne. As the eagles attempted to fly up to the meat, they carried the throne up, but, inevitably, they grew tired and the throne came crashing down.

Cover of al-Firdawsi's *Book of Kings*.

Pre-Islamic Arabic legends also have stories about flying magicians and sorcerers, supernatural powers, birds or just feathers. For Muslims, flight has a spiritual dimension. The pious soul reaches for goodness until it attains a certain level, then it rises above.

The first Muslim, and perhaps person, to make a real attempt to construct a flying machine and fly was Cordoban 'Abbas ibn Firnas in the 9th century. He was the usual polymath of the time, becoming a renowned poet, astrologer, musician, astronomer and an engineer; but his greatest fame was for constructing a flying machine, the first of its kind capable of carrying a human into the air. He flew successfully a number of times over desert regions, in proving his designs before attempting his two famous flights in Cordoba.

The first flight took place in 852, when he wrapped himself in a loose cloak stiffened with wooden struts and jumped from the minaret of the Great Mosque of Cordoba. This cloak was his 'wings', and he glided as though wearing a parachute or hang glider. The attempt was unsuccessful, but his fall was slowed enough that he got off with only

After observing birds landing, Abbas ibn Firnas realized that a tail was needed to land accurately. He had not noticed this previously and crashlanded when he flew.

minor injuries, making it at least one of the earliest examples of a parachute jump. Western sources wrongly gave him a Latin name calling him Armen Firman, instead of 'Abbas ibn Firnas.

Ibn Firnas was one to learn from experience, and he worked hard to improve his next design. Accounts from various eye witnesses and medieval manuscripts described it as machine consisting of large wings. So about twelve hundred years ago, one nearly seventy year-old man, 'Abbas ibn Firnas, made a flight machine from silk and eagle feathers.

In the Rusafa area on the outskirts of Cordoba in Spain, Ibn Firnas mounted a hill near a mountain named then as *Jabal al-'arus* or Mountain of the Bride. At a scheduled time, after Ibn Firnas had completed the final touches on his machine, a large crowd of people gathered to witness his flight.

Appearing before the crowd in his bird costume, made from silk covered with eagle feathers which he tightened with fine stripes of silk, Ibn Firnas explained with a piece of paper how he planned to fly using the wings fitted on his arms: 'Presently, I shall take leave of you. By guiding these wings up and down, I should ascend like the birds. If all goes well, after soaring for a time I should be able to return safely to your side.'

He flew to a significant height and hung in the air for over ten minutes before plummeting to the ground, breaking the wings and one of his vertebrae. After the event, Ibn Firnas understood the role played by the tail, when birds land, telling his close friends that birds normally land on the root of the tail which did not happen for him because he didn't have one.

All modern aeroplanes land on their rear wheels first, which makes Ibn Firnas's comment very relevant and ahead of its time. Recording the event, one witness wrote: 'He flew a considerable distance as if he had been a bird, but in alighting again on the place where he started from, his back was very much hurt. For, not knowing that birds when they alight come down upon their tails, he forgot to provide himself with one.'

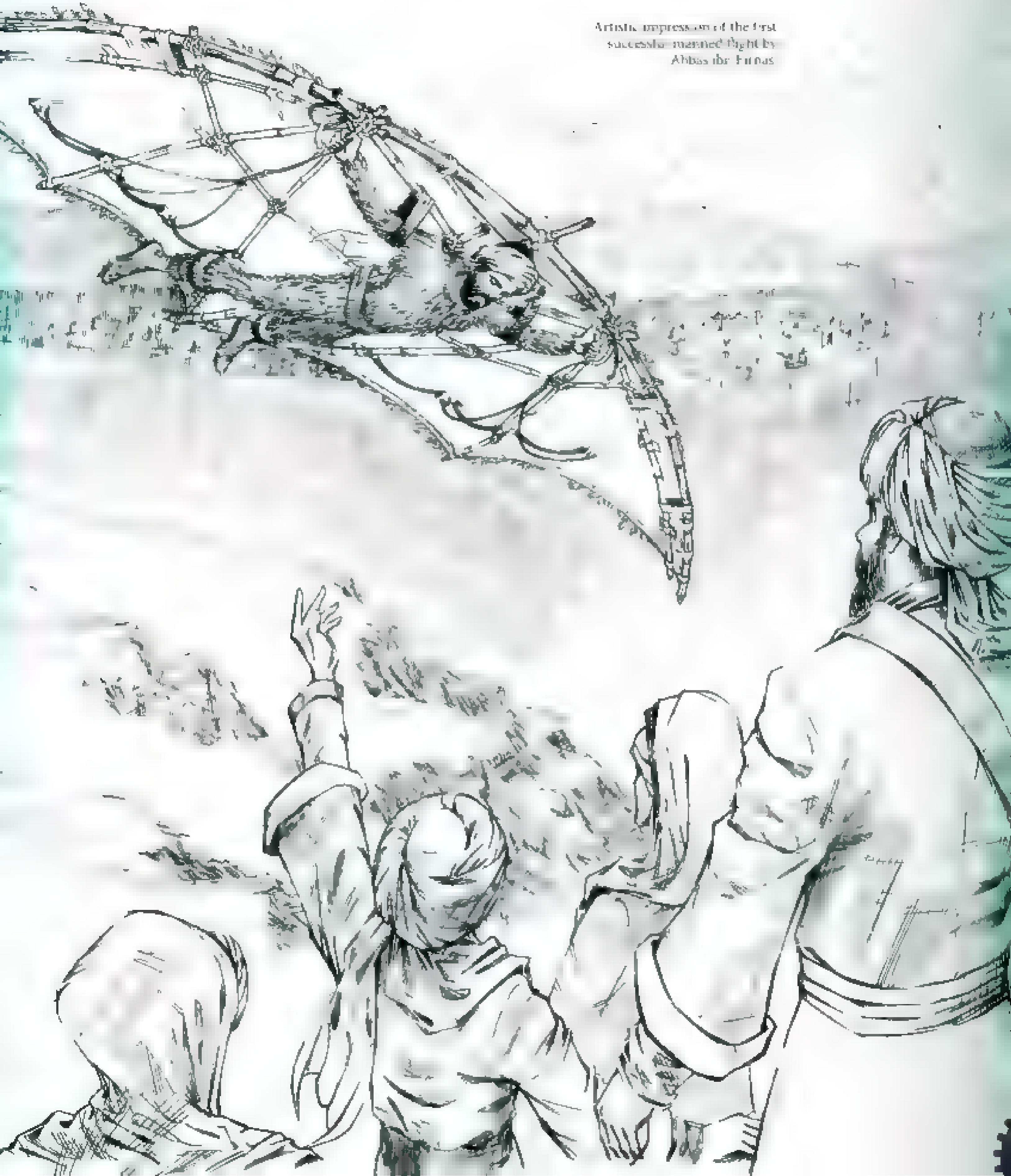
Statue of Leonardo da Vinci outside the Uffizi, Florence, Italy

It would be centuries until Leonardo da Vinci's flight drawings and the Wright brother's first 'flight'

Unfortunately, the injury Ibn Firnas sustained in the flight prevented him from carrying out further experiments to incorporate his belated discovery of the need of a tail. However, he was an enterprising man, and he must have modified his machine, or more probably guided somebody, perhaps one of his apprentices, to create a newer version.

The existence of such a machine was mentioned in a manuscript by Roger Bacon, who described it as an ornithopter. In 1260, Bacon wrote *On the Marvellous Powers of Art and Nature* including two possible ways a person might fly. One is a rough description of what was later to become known as an ornithopter. The other is a more detailed description of a globe filled with 'ethereal air' Bacon claims, "There is an instrument to fly with, which I never saw, nor know any man that hath seen it, but I full well know by name the learned man who invented the same.' It is known that Bacon studied in Cordoba, the homeland of Ibn Firnas. It is likely that the description of the ornithopter could have been taken from Muslim contemporary manuscripts in Spain that have since disappeared without a trace.

Ibn Firnas died in 887, and none of his original works were saved for today. His life has been reconstructed from a few verses and from the information given by the chroniclers of the time.



Artistic impression of the first successful manned flight by Abbas ibn Firnas

Left to right: A depiction of the flight of Hazarfen Ahmed Celebi in 1638 from Galata Tower near the Bosphorus in Istanbul; an artistic impression depicting the first manned rocket flight flown by Lagari Hasan Celebi in 1633 on the night that Sultan Murad IV's daughter was born. Lagari Hasan was launched into the sky by a seven-winged rocket that he had invented which used a mixture of gunpowder paste.

After Ibn Firnas, Muslims and non-Muslims pursued the endeavour of flying, and many more flight attempts were made. Al-Juhari, a Turkistani teacher launched himself from the minaret of Ulu Mosque in 1002 using wings made from wood and rope. He died instantly on impact. Eilmer of Malmesbury was an 11th-century English Benedictine monk who also forgot the use of a tail, and broke both his legs as he jumped from a tower in 1010 after gliding six hundred feet.

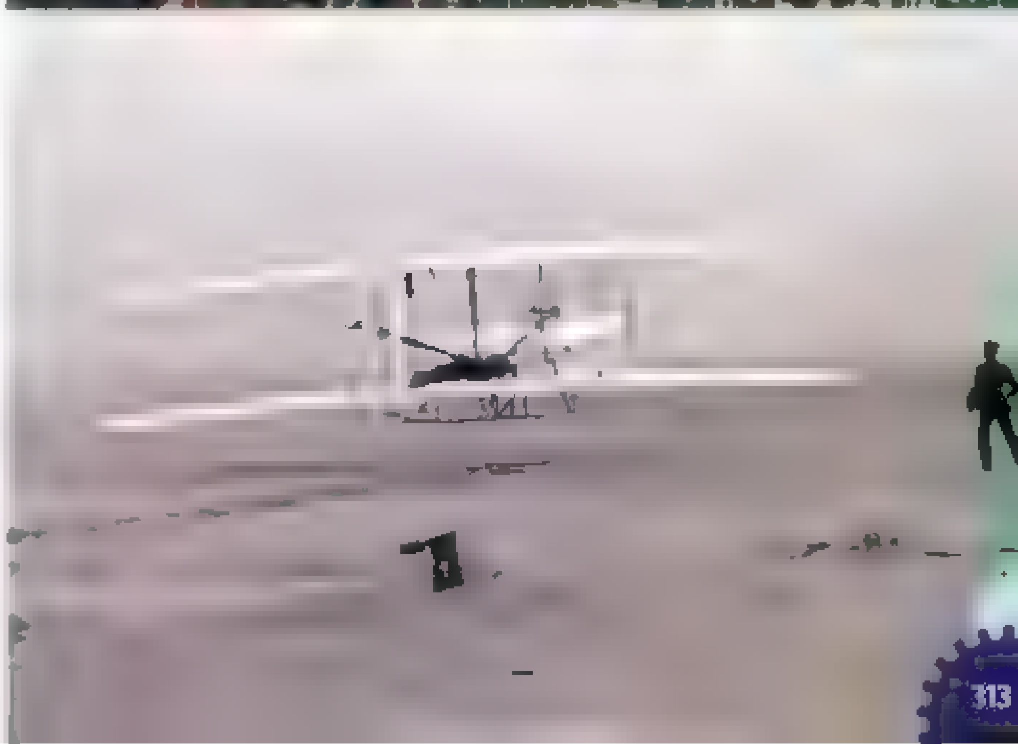
After these two, aviation history is silent until the works of the famous Florentine artist and scientist, Leonardo da Vinci, are mentioned. Leonardo remains the leading engineer to establish proper scientific thinking on the quest for flight. Although he did not attempt to fly himself, da Vinci discussed and drew on paper many sketches relating to flight and flying, including a bird-winged machine known as an ornithopter, a machine designed to be strapped to a man's back. Other sketches included a glider and, according to some, even a helicopter.

In 1633, a Turk named Lagari Hasan Celebi invented the first manned rocket, which he launched using about three hundred pounds of gun powder as the firing fuel. The event is recorded by an artist's sketch drawing. William E. Burrows in his book *This New Ocean, The Story of the First Space Age* says that '... there was a Turk named Lagari Hasan Celebi, who ... was shot into the sky by fifty-four pounds of gunpowder to celebrate the birth of Sultan Murad IV's daughter, Kaya Sultan. ... The rocket then carried Celebi high into the air, where he opened several "wings", and then glided to a safe landing in front of the royal palace. Celebi was rewarded with a pouch of gold, made a cavalry officer, and is said to have been killed in combat in the Crimea.'

Hazarfen Ahmed Celebi, a 17th-century Turk, used eagle feathers stitched on his wings to fly. After nine experimental attempts, he decided on the shape of his wings. His most famous flight took place in 1638 from the Galata tower near the Bosphorus in Istanbul, and he successfully landed on the other side of the river. According to the Turkish historian, Evliya Celebi, who witnessed the feat and recorded it in his book *A Book of Travel*, the famous Turkish flyer used al-Juhari's calculations with some corrections and balancing adjustments, derived from studying the eagle in flight. Hazarfen earned a reward of a thousand gold pieces for his achievement, and a Turkish postal stamp bears tribute to his historic flight.

After the successful flight over the Bosphorus, the Montgolfier brothers were the next to pub-

Top to bottom: An illustrative print showing the balloon, "Le Flesselles" ascending over Lyon, France, on January 19, 1784, carrying seven passengers including Joseph Montgolfier and Jean François Pilâtre de Rozier; the first flight by the Wright Brothers in 1903



licly air their hopes for flight with a model hot air balloon whose passengers were a sheep, a duck and a cockerel. A few weeks later Pilatre de Rozier, a science teacher, and the Marquis d'Arlandes, an infantry officer, became the first human air travellers when, in a hot air balloon, they flew for nine kilometres over Paris.

Nineteenth-century aeronautics was dominated by the German Otto Lilienthal, who studied the lifting power of surfaces, the best form of wing curvature and the movement of the centre of pressure with different wing angles, an important factor in the stability of aircraft. He was a great hang glider, but died in flight in the Berlin hills in 1896 when a gust stalled his machine and he was unable to regain control.

The Wright brothers are probably the most famous names today in flight and the centenary of their 1 December 1903 flight has just recently passed.

Wilbur Wright's key insight was to study birds, a lesson Ibn Firnas learned too. Wilbur realized that birds keep their lateral balance, or control when banking, by twisting their wings. He devised a kite that reproduced the same effect mechanically, allowing it to roll one way or the other as desired.

Before developing a powered aircraft, the brothers used gliders, aiming 'to escape accident long enough to acquire skill sufficient to prevent accident.' They also hit on the essential principle of combining rudder control and roll for smoother balanced turns. By 1908 Wilbur Wright could demonstrate his aeroplane in France, and within the year Henri Farman and Louis Bleriot were making extended flights.

All this history of aviation, and even space travel, started with the humble beginnings of one man, 'Abbas ibn Firnas, who was one of the first to try out his ideas when he glided with his eagle feathers and silk.

Layla and Majnun at school in a 15th century Persian manuscript

REFERENCE

'[illegible] before fact as a little child, [illegible] wherever and [illegible] leads, or you [illegible] nothing.'

Thomas Huxley

[illegible]

[illegible] the only way to true knowledge [illegible]

[illegible] 'Authors and Treatise' section [illegible]



Personalities from the Past

THROUGHOUT THIS BOOK, you've read how Muslim men and women have contributed to all our daily lives. Here now is a Who's Who of some of the big names from a thousand years ago.

'Abbas ibn Firnas

Full name: 'Abbas Abu Al-Qassim ibn Farnas ibn Wirdas al-Takurini

Born: 9th-century; Andalusian descendent from a Berber family residing in Takuronna (now Ronda)

Died: 887

Most influential work: Producing a flying machine, crystal and a planetarium

Go to: 'Fine Dining' in Home; 'Glass industry' in Market; and 'Flight' and 'Observatories' in Universe

It's difficult to pin one profession on Cordoban Abbas ibn Firnas because he had numerous talents, including poetry, astrology, music and astronomy. He was also fluent in Greek, and made translations of philosophical and musical manuscripts.

After perfecting the technique of cutting rock crystal (quartz) and producing glass, he made a kind of glass planetarium, complete with artificial thunder and lightening.

His most famous achievement is the construction of a flying machine, the first of its kind capable of carrying a human into the air.

Unfortunately he left no trace of his original works, and his biography was reconstructed only from a few verses and information from eye witnesses left to us in numerous documents.

Al-Jazari

Full name: Badi al-Zaman Abu al-'Izz Isma'il b. al-Razzaz al-Jazari

Born. Birth date not known, but we do know he served the Urtuq kings of Diyarbakir (now in South East Turkey) from 1174-1200

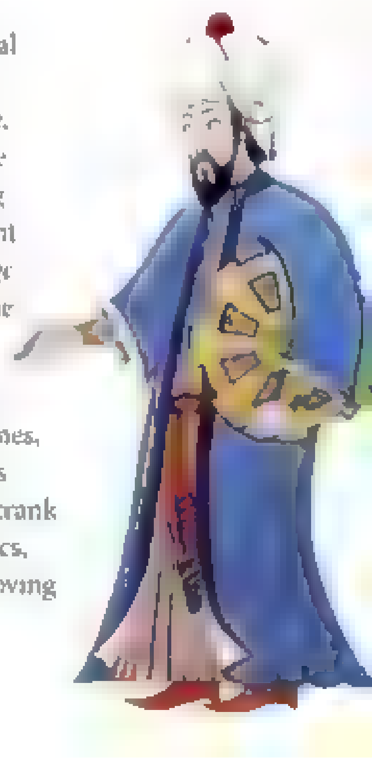
Died: Date not known

Most influential work: *Al Jami Bain Al-Ilm Wal Amal Al-Nafi fi sinaat Al Hiyal*, or *The Book of Knowledge of Ingenious Mechanical Devices*

Go to: 'Cleanliness,' 'Clocks' in Home; and 'Raising Water' in Market.

Today we might call al-Jazari a mechanical engineer, and he was an outstanding one at that. There is little known about his life, but what we do know is that he was in the service of Nasir al-Din, the Artuqid, King of Diyarbakir who asked him to document his inventions in a manual, the '*Knowledge of Ingenious Mechanical Devices*,' which he completed in 1206.

Before this, he had built many machines, including clocks and water raising machines, and a large number of mechanical devices that revolutionized engineering, like the crank shaft. He is possibly the first to use robotics, as many of his machines incorporated moving figures.



Al-Kindi

Full name: Abu Yusuf Yaqub ibn Ishaq al Sabbah al-Kindi

Born: About 801 in Kufa, Iraq

Died: 873

Most influential work: Wrote over 361 works on a variety of subjects including '*The Book of the Chemistry of Perfume and Distillations*'

Go to: 'Sound System,' 'Cleanliness,' 'Vision and Camera' in Home; 'Chemistry,' 'House of Wisdom,' 'Translating Knowledge' in School; 'Pharmacy' in hospital, 'Commercial Chemistry' in Market; 'Earth Science' and 'Natural Phenomena' in World

Al-Kindi was an encyclopaedic man, working as a physician, philosopher, mathematician, geometer, chemist, logician, musician and astronomer. A son of the governor of Kufa, he studied there and Baghdad's House of Wisdom, where he gained a high reputation at the Caliphs' court for translation, science, and philosophy. Caliph al-Mutassim also chose him as tutor to his son Ahmad.

His contributions include an introduction to arithmetic, eight manuscripts on the theory of numbers, and two on measuring proportions and time. He was the first to develop spherical geometry, and used this in his astronomical works. He wrote on spherics, the construction of an azimuth on a sphere, and how to level a sphere. As a musician he used musical notation and played a part in the development of the *'ud* (lute).

Al-Zahrawi

Full name: Abul Qasim Khalaf ibn al-Abbas al-Zahrawi, known in the west as Abulcasis

Born: 936 in Medinat al-Zahra near Cordoba, Spain

Died: 1013

Most influential work: *Al-Tasrif liman 'Ajiza 'an Al-Ta'lif*, shortened to *al-Tasrif*, and translated as '*The Method of Medicine*', which became a central part of the medical curriculum in European countries for many centuries.

Go to: 'Cleanliness' in Home; 'Translating knowledge' in School; 'European Medicine,' 'Instruments of Perfection,' 'Pharmacy' and 'Surgery' in Hospital.

Al-Zahrawi was a revolutionary physician and surgeon of Umayyad Spain. His thirty-volume book, *al-Tasrif*, gave detailed accounts of dental, pharmaceutical, and surgical practices, and it was one of the most influential medical encyclopaedias of the time.

His real surgical breakthroughs included his discovery of the use of catgut for internal stitching, and administering drugs by storing them in catgut parcels that were ready for swallowing, known today as the capsule.

He also designed and illustrated more than two hundred surgical instruments like syringes, droppers, scalpels and forceps, and his detailed diagrams of these figured prominently in medieval medical texts and journals in Europe and the Muslim world for centuries to come. Many modern surgical instruments have changed little from his original designs.

Fatima al-Fihri

Full name: Fatima Al-Fihri

Born: 9th century

Died: 841

Most influential work: Building the college mosque complex of al-Qarawiyin in Fez, Morocco in 841 CE

Go to: 'Universities' in School

Fatima al-Fihri was a young, well educated princess who received a large amount from her father, a successful businessman. She vowed to spend her entire inheritance on building a mosque and learning centre for her Qairawaniyyin community, which was completed in 859. This developed into Morocco's number one university.

Studies included astronomy, the Quran and theology, law, rhetoric, prose and verse writing, logic, arithmetic, geography, medicine, grammar, Muslim history, and elements of chemistry and mathematics. This variety of topics and the high quality of its teaching drew scholars and students from all over.

Fatima's sister, Maryam, had simultaneously constructed al-Andalus Mosque in the vicinity of Qairawaniyyin. These two neighbourhoods became the nuclei to the city of Fez.

Ibn al-Haitham

Full name: Abu 'Ali al-Hasan Ibn al-Haitham, known in the West as Alhazen

Born: 965 in Basra, Iraq

Died: 1039 in Cairo, Egypt

Most influential work. *Kitab al-Manazir* or *Book of Optics*, which formed the foundations for the science of optics. The Latin translation had an enormous impact on Roger Bacon, Witelo, Leonardo da Vinci, Descartes and Johan Kepler, centuries later.

Go to: 'Vision and Camera' in Home; 'Translating Knowledge' in School; 'Natural Phenomena' in World; and 'The Moon' in Universe

Ibn al-Haitham revolutionised optics, taking the subject from one being discussed philosophically to a science based on experiments. He rejected the Greek idea that an invisible light emitting from the eye caused sight, and instead rightly stated that vision was caused by light reflecting off an object and entering the eye.

By using a dark room with a pinhole on one side and a white sheet on the other, he provided the evidence for his theory. Light came through the hole and projected an inverted image of the objects outside the room on the sheet opposite. He called this the '*qamara*', and it was the world's first camera obscura.

Ibn Battuta

Full name: Abu Abdullah Muhammad ibn Battuta

Born: 1304 in Tangier, Morocco

Died: 1368 or 1370

Most influential work: The *Rihla* or his travel book, narrated by him and written by Ibn Juzayy, a Royal Scribe, under the patronage of Abu 'Inan, the Sultan of Fez and Morocco

Go to: 'Raw Jewels', 'The Checkout', 'Trade' in Market; 'Public Baths' in Town; 'Travellers and Explorers' in World

Ibn Battuta left his hometown of Tangier in Morocco as a twenty-one-year old, about 680 years ago. He set off as a lone pilgrim and didn't return for twenty-nine years. In this time, he covered over 75,000 miles, through forty-four modern day countries travelling on horse, cart, camel, boat and foot. This journey took him through North, West, and East Africa, Egypt, Syria, Persia, the Arabian Gulf, Anatolia, the Steppe, Turkistan, Afghanistan, India, Maldives, Ceylon (Sri Lanka), Bengal, Sumatra, China, Sardinia and Spain. By the end he had visited Mecca four times, and had met, and could name, over 1,500 people, including sixty heads of state.

He was then asked by the Sultan of Fez and Morocco to record all this in his *Rihla*, and this is our window into the 14th century world because he has left some of the best eyewitness accounts of culture, customs, people, animal and plants of the medieval world stretching from Cordoba to Canton.

Ijliya al-Astrulabi

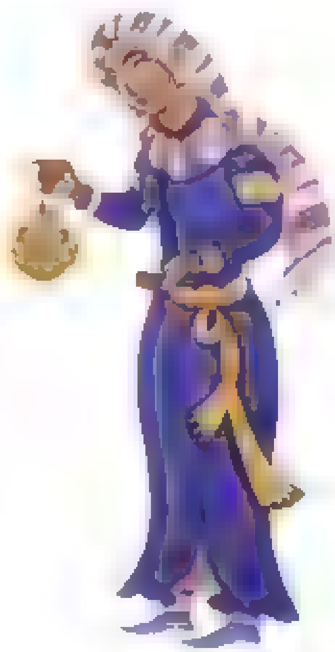
Full name: Maeriam al-Ijliya al-Astrulabi

Born: 944 in Aleppo, Syria in the era of Saif ad-Dawla

Died: 967

Most influential work: She was the daughter of Al-Ijli al-Astrulabi and continued her father's work of making astrolabes.

Go to: 'Astrolabe' in Universe



Jabir ibn Hayyan

Full name: Abu Musa Jabir ibn Hayyan, known in the West as Geber

Born: 722 in Tus, Iran

Died: 815 in Kufa, Iraq

Most influential work: Devising and perfecting the processes of sublimation, liquefaction, crystallization, distillation, purification, amalgamation, oxidation, evaporation, and filtration, and producing sulphuric acid by distilling alum

Go to: 'Chemistry' in School; 'Commercial Chemistry' in Market

Jabir ibn Hayyan is generally known as the 'father' of chemistry. The son of a druggist and perfume maker, he worked under the patronage of the Barmaki vizier during the Abbassid Caliphate of Harun al-Rashid. This meant that he shared some of the effects of the downfall of the Barmakis and was placed under house arrest in Kufa, where he died.

His work wasn't all in the lab and had practical applications, as he described processes for the preparation of steel, hair-dyes, metal refinement, dyeing cloth and leather, making varnishes to waterproof cloth, and illuminating manuscript ink. Some of his most groundbreaking work was in acids and in discovering sulphuric and hydrochloric acid.

Sinan

Full name: Koca Mimar Sinan

Born: 1489

Died: 1588

Most influential work: Designing and building over 477 buildings, including the Selimiye Mosque in Edirne, which has the tallest, earthquake-defying minarets in Turkey

Go to: 'Architecture' in Town

Sinan was the son of Greek Orthodox Christian parents who embraced Islam. His father was a stonemason and a carpenter and from an early age Sinan followed in his footsteps, learning the skills of his trade. Aged twenty-one, he was recruited into the Janissary Corps and as a conscript, he mentioned that he wanted to learn carpentry. This saw him eventually building ships, wooden bridges and all sorts of temporary wooden constructions.

Through military service he participated in a number of Ottoman campaigns and gained experience building and repairing bridges, defences and castles. The Ottoman Sultans noticed his talents and he became their chief architect, constructing mosques, schools and other civic buildings all around the Muslim (Ottoman) world, from Turkey to Damascus, Mecca and Bosnia.

He is also honoured with a crater on Mercury being named after him.

Zheng He

Full name: Born as Ma He; then his name changed to Zheng He as he was awarded the supreme command of the Chinese Imperial Household Agency.

Born: 1371 in Kunming, China

Died: 1433 in India

Most influential work: Transformed China into the 15th century's regional, and perhaps world, superpower by making seven monumental sea voyages.

Go to: 'Sea Exploration' in World

Zheng He was the admiral of the Chinese fleet, and within twenty eight years of travel, he'd visited thirty seven countries in the name of trade and diplomacy. The expeditions covered more than 50,000 km, and his first fleet included 27,870 men on 317 ships. Today it is not known how his ships, that were over four hundred feet long, were built without metal in them. These massive vessels were five times as big as the vessels of other European explorers like Vasco da Gama and were described as 'swimming dragons', because they were dotted with dragon's eyes to help them 'see.'

Some of the lands the great fleet visited include Java, Sumatra, Ceylon, Siam, the East Indies, Bengal, the Maldives, the Persian Sultanate of Ormuz, Ryukyu and Brunei, Mogadishu, Mombasa and other East African ports, Borneo, Mecca; they even possibly rounded the Cape.

These voyages fostered scientific discovery and the search for gems, minerals, plants, animals, drugs and medicine. They also improved navigational and cartographical knowledge of the world; developed international relations, and traded large quantities of cargo, including silk and cotton goods, porcelain, gold and silverware, copper utensils and iron implements. They also carried live animals including giraffes and ostriches, had watertight bulkheads to hold live fish and also make bath houses, and used otters to round up fish into large nets.

Europe's Leading Minds

THE FOLLOWING MEN have all engaged in groundbreaking work and are remembered for their outstanding contributions to modern day science and discovery. Their genius rose above the mediocrity of their day in the same way that outstanding Muslims had previously shown. It was the work that the Muslims left behind, described in this book, which provided the foundations for this next leap of knowledge and invention.

Roger Bacon (1214–1292)

Leonardo da Vinci (1452–1519)

Roger Bacon (1214–1292)

- This Oxford scholar is known as the originator of the experimental method in Europe, and he received his training from the pupils of Spanish Moors. He spoke Arabic and never tired of telling people that knowledge of Arabic and Arabic science was the only way to true knowledge.
- Bacon quotes Ibn al-Haitham or refers to him at almost every step in the optics section of his *Opus Maius*. Part VI of this also rests almost entirely on the findings of Ibn al-Haitham, especially in areas relating to the intromission theory of vision. It was Ibn al-Haitham who introduced the scientific, experimental method, and it was this that Bacon picked up on also.
- Al-Kindi was another source of inspiration for Bacon, and his two treatises on geometrical and physiological optics were used by the European.
- Ibn Firnas's flying machine inspired Bacon's flying machine or ornithopter, which he described in his manuscript *De Mirabili Potestate Artis et Naturae* or *On the Marvellous Powers of Art and Nature* from 1260. It is known that Bacon studied in Cordoba, the homeland of Ibn Firnas.
- Bacon's writing on gunpowder was based on Muslim sources, and the so-called Latin book *Liber Ignium of Marcus Graecus*, which gives many recipes for making gunpowder, was originally in Arabic and translated in Spain.
- Roger Bacon became acquainted with Muslim chemistry from the Latin translations of Arabic works, and believed in the great importance of alchemy, and in transmutation.
- His chief guide in medicine was the *Canon* of Ibn Sina, which he cites as frequently as all those other writers combined.
- The book that had the greatest impact upon Bacon's method of thinking, and made him different from his western contemporaries, was *The Book of the Secret of the Secrets* by 9th century Zakariya' al-Razi (known in the West as Rhazes). In Latin, this was *Secretum Secretorum*.

Leonardo da Vinci (1452–1519)

- Leonardo da Vinci was an Italian painter, sculptor, architect, musician, engineer, mathematician and scientist, and a key figure in Renaissance Europe.
- Da Vinci drew 'The Vitruvian Man,' a man of perfect proportions in two superimposed positions with his arms apart, appearing in a circle and square, which illustrated the text of the Roman Canon of Vitruvius. Da Vinci's drawing was seen as innovative because he said the man's centre, when drawn in a square, was not his naval, as the Canon stated, but lower. However, five centuries

earlier Muslim scholars *Ikhwan al-Safa'* or the Brothers of Purity from the 10th century had come to the same conclusion, saying that the centre of the figure was only the navel for a child under seven and after this the centre moved to the groin area.

- Historians have acknowledged Ibn Sina's *Book of Cure, Healing or Remedy from Ignorance* as an inspiring source of thought for the founders of geometrical thought in Europe, including Leonardo da Vinci.
- Ibn al-Haitham invented the camera obscura long before Leonardo da Vinci, who produced the full and developed camera design.
- He found arabesque designs fascinating and worked out his own complicated patterns. The Muslim knot, in particular, intrigued him so he produced two plates of six knots, which were later reproduced in circular copper engravings by one of his followers in Milan around 1483 and 1499.

Nicolas Copernicus (1473–1543)

- Polish scientist Copernicus is said to be the founder of modern astronomy.
- Many of his theories were based on those of Nasir al-Din al-Tusi and Ibn al-Shatir. Ibn al-Shatir's planetary theory and models are mathematically identical to those prepared by Copernicus over a century later. Copernicus would have come into contact with these in Italy, where he studied.
- Another influence on Copernicus is believed to have been the famous Toledan Tables written by al-Zarqali, who was born in 1028.
- It is known that he relied heavily on the comprehensive astronomical treatise of al-Battani that included star catalogues and planetary tables of al-Battani.
- He relies profusely on al-Zarqali and al-Battani in his book *De Revolutionibus*.

Tycho Brahe (1546–1601)

- This leading Danish Renaissance astronomer was credited for many influential works, including the production of the quadrant and one of Europe's leading observatories.
- He is renowned for rediscovering the Moon's variation, which was first discovered by a Muslim astronomer Mohammed Abu al-Wafa al-Bouzjani about six hundred years earlier.
- The instruments used by this famous 16th century observational astronomer were very similar to those used by Muslim astronomers. His famous mural quadrant was like those developed in eastern Islam, especially by astronomer Taqi al-Din.

Johannes Kepler (1571–1630)

- Kepler is renowned in the West for discovering the laws of planetary motion, his work on optics; as the founder of the first correct mathematical theory of the camera obscura; and the first correct explanation of the working of the human eye, with an upside-down picture formed on the retina.
- Ibn al-Haitham's influence can easily be detected in Kepler's work, as the former had revolutionized optics six hundred years earlier. His *Kitab al-Manazir* or *Book of Optics* was translated into Latin by Gerard of Cremona and called *Perspectiva* or *De aspectibus*.
- Both Kepler and Descartes relied upon Ibn al-Haitham's studies on the refraction of light, and Kepler took up where Ibn al-Haitham left off.
- He developed the camera obscura after its first discovery by Ibn al-Haitham, improving it with a negative lens behind the positive lens, which enlarged the projected image (the principle used in the modern telephoto lens).

Nicolaus Copernicus (1473–1543)

Tycho Brahe (1546–1601)

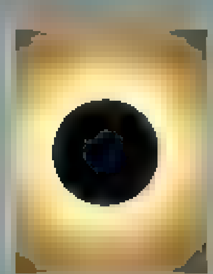
Johannes Kepler (1571–1630)

16th century close-up of a manuscript showing an Ottoman military camp. This is small part of a large manuscript depicting an army camp in which there is a bazaar including hot food take away.

TIMELINE

forget history..."

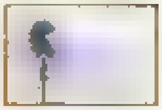
every man's judgement

Islamic Events

632
Prophet Muhammad (pbuh) dies and Abu Bakr becomes the first caliph

644



661
The Umayyad dynasty [illegible]

[illegible]
Building begins of the [illegible] Rock [illegible] Jerusalem

710
[illegible] Spain

722
[illegible]

750
[illegible]

786
Caliph Harun al-Rashid [illegible] the House of [illegible] Baghdad

787
[illegible]

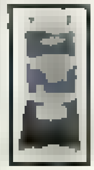
790
[illegible]

777
[illegible]

795
[illegible]

800
Caliph Harun al-Rashid presents [illegible] with a [illegible] that strikes the hours

801
Al-Kindi discovers the science of decryption or cryptanalysis



813
- Caliph al-Ma'mun [illegible] the House of Wisdom
- Translation works [illegible]

828
[illegible]

850
Banu Musa brothers publish their most renowned engineer[illegible]

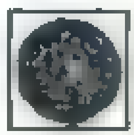
858
Al-Battani is born and [illegible] cal measurements with fine accuracy

859
Al-Qarawiyin [illegible] in Fez [illegible] Fatima al-Fihri [illegible]

700

800

European Events



785
[illegible]

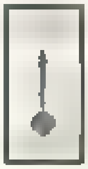
Foundation for Science Technology and Civilisation

...versity
...ec by

...
...Razi is born (dies in 925) and discovers
...difference between measles and smallpox
...also writes the first soap recipe

887
Abbas ibn Firnas dies in Cordoba after building a flying machine, manufacturing glass and establishing a crystal industry

[illegible]
The Fatimids rule Egypt and North Africa, then nine years later Sicily



957
Al-Masudi, a cartographer and travel historian describes his visit to the outskirts of Bak...

950
Al-Farabi from Baghdad invents the rebec, the ancestor of the violin

[illegible]
Az-Zahrawi is born in Cordoba and introduces cat gut and [illegible] into surgery

965
Ibn al-Haitham is born. He later provides the scientific explanation of vision and significantly develops the field of [illegible]

[illegible]
Al-Azhar university was founded by the Fatimids in Cairo

973
Al-Biruni is considered as a key founder of modern [illegible]

980
Leading physician Ibn Sina is born and discovers that disease spreads through contaminated water and tuberculosis is contagious

[illegible]
Building begins [illegible] Mosque in Toledo, Spain

1009
Astronomer Ibn Yunus [illegible] in Cairo after inventing the Raqqas for time keeping (the pendulum)

1040
[illegible] contest the Abbasids in Baghdad

1056
The Al-Moravids establish their rule over North Africa, Morocco, Algeria and Tunisia

1066
The Nizamiyya madrasa, the first school, is built by Nizam al-Mulk (1018–1092), the Seljuk minister

1085
Ibn Bassal's *Book of Agriculture* revolutionizes farming. He is from Toledo, Spain

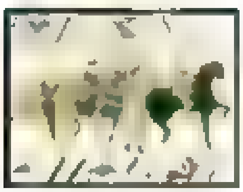
1099
Al-Idrisi is born and produces a world map, plus the first known globe for Norman King Roger II of Sicily

1110
Ibn Tufayl is born and writes *The Story of Hayy ibn Yaqzan*, an inspiration for Robinson Crusoe

900 — 1000 — 1100

1010
[illegible]

1060
Construction [illegible]



1066
The Norman conquest of England triggers the flow of Muslim motifs and ideas into the country

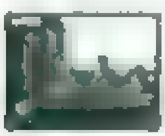
1085
- A centre of translation at Toledo is established, converting Arabic books into Latin
- [illegible] its library

1096
The First Crusades begin providing a good opportunity of contact with Muslim learning and civilization

1098
The first rib vaulting appears in Durham Cathedral introduced by the Normans

1112
Petrus Alphonsi, a Spanish Jew converted to Christianity, becomes a member of the team of physicians of King Henry I. Petrus introduced Islamic astronomy to England, and translated texts from Arabic for the first English scientists

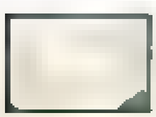
[illegible]
The Tower of St Edmund at Bury in England is built in a Muslim fashion



1129
Lalys, a Muslim prisoner, is taken by his master Richard de Grandville to England to build the abbey ... Neath [illegible]). He impresses King Henry I who nominates him as his architect

1130 Arrow slits enter English castle...

- Daniel of Morley travels to Cord... learn mathematics and astrono... returning to England to lecture a...



1143
Robert of Chester translates the Quran. Two years later he translates works of al-Khwarizmi an... algebra. He also compiles tables for the longitude of London (1149) from those of al-Battani and...

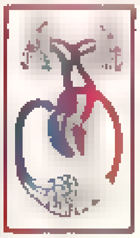
The leader Salah al-Din al-Ayyubi regains Jerusalem

1197
Ibn al-Baytar is born in Malaga to become a leading botanist

1206

1210

pulmonary circulation



1250

1258
and rule Baghdad

1325

1332
Ibn Khaldun is born and lays the foundations of

1347
Black Death reaches Alexandria and Cairo

1405

鄭和

1200 1300 1400

1215

becomes the

[illegible]
Leonardo Fibonacci introduces Arabic numerals and mathematics to Europe. He learnt

1236 The Christians take Cordoba

1187 Machicolation is introduced in Norwich

1238 The Christians take Valencia

1186
The Bishop of Hereford, William de Vere, travels east (including Jerusalem) and encourages the introduction of translated Muslim scientific knowledge into Hereford, England

1185
Temple Church is built in London by the Templars imitating the Dome of the Rock, Jerusalem

1347 Black Death

1330 Giotto's painting Madonna and Child uses tiraz, bands of Arabic inscriptions which mark royal garments and other textiles from the Muslim world

1323 Irishmen Simon Simeon and Hugh the Illuminator visit the Holy Land and return with inspirations that greatly affect art work in England and Ireland

1311 The Ecumenical Council of Vienne decide to establish schools at universities like Paris, Oxford, Bologna, and Salamanca teaching Arabic and Islamic studies

1309

1307 Dante's Divine Comedy involves imagery from Muslim literature like Prophet Muhammad's journey to heaven, the works of Abu al-Ala al-Maarri and Quranic descriptions of hell's punishments

1303 The port of Sandwich, Kent, receives imports of Moorish pottery. One of these dishes is now at th

1293

1290

1291 Fall of last Christian outposts in the Holy Land

1289 Eleanor of Castile, the Spanish wife of Edward I, orders four thousand pots of Malaga

1267 Marco Polo starts his twenty four year journey

1260 Roger Bacon publishes his Epistol showing influences of Muslim scholars

1255 Queen Eleanor, the Castilian Bride of King Edward I, brings Andalusian carpets to England in her dowry

1254 King Alfonso el Sabio establishes Latin and Arabic colleges in Seville and commissions the translation of Arabic texts

1248 The Christians take Seville

1245 Albert the Great arrives in Paris, as tradition holds, wearing Arab dress

Beg publishes his
catalogue

1492
Ferdinand of Aragon and Isabella of Castile end Muslim rule in Spain

1453
The Ottomans make Constantinople their new capital

1513

1520
The Safavids set their

1633
Lagari Hasan Celebi flies the first manned rocket

[illegible] observatory of (Taqi) al-Din is finished. He also invents a 6-cylinder [illegible]

1500

1600

1452
Leonardo da Vinci is born. Drawing from the achievement of Muslim scholars, he lays the foundations of the European Renaissance

... ascent

...seum of London

1571
[illegible] Drawing from the works of [illegible]

1628
[illegible]

Galileo Galilei [illegible] in 1642)

1558
[illegible] probably Europe['s first] observatory [illegible]

[illegible] dies in 1727)

1650
A [illegible] coffee house [illegible] first brought coffee into the UK

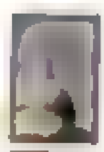
[illegible] publishes *De Revolutionibus*

A cafe called 'Sultaness Head' is opened in Cornhill, Lloyds of London

1518
Cardinal Wolsey orders sixty Damascene carpets

1537
- A portrait made for Henry VIII by Holbein shows him standing on a Turkish carpet with its Ushak [design]
- Ibn Rushd's *General Rules of Medicine* is translated into Latin as *Colliget*

1660
Louis XIV receives the Ottoman ambassador Suleiman Agha. Agha introduces France to coffee



1679
The Turkish bath or 'bagnio' is opened at Newgate Street, now Bath Street, in London

1506
Sultan Bayazid invites Michelangelo to perform the bridge construction, but negotiations fall through

1497
Venice publishes a translation of *al-Tasrif* by az-Zahrawi. Basel (1541) and Oxford (1778) follow suit

[illegible]
Sir Christopher Wren designs St Paul's using the duality of dome and minaret depicted in Muslim mosques. The dome was raised on squinches, another Muslim tradition

1492
- The Christians take Granada, the last Muslim stronghold in Europe

1593
The *Canon* of Ibn Sina is printed in Rome and will soon become a staple in European medical curriculum

Map of Major Muslim Contributions

Dar al-Islam, or the Muslim world, stretched over three vast continents, from Toledo in Spain, through Arabia, Indonesia to China and as far south as East Africa. It reached its peak in the 12th century under the Abbasids.

Cities in the Middle East and Spain became global centres of culture, trade and learning. Their atmosphere of tolerance and creativity stimulated groundbreaking Muslim advances in medicine, engineering, philosophy, mathematics, astronomy and architecture so explore the map below to see what happened, where - and when!

Authors and Treatises

BELOW ARE THE TITLES OF MANUSCRIPTS, treatises and books of some of the Muslim scholars mentioned in this book, and details of where some of these can be found.

Locating original manuscripts is difficult because often, since a thousand years have passed, they don't exist any more. Reasons for this vary from libraries being burnt in the Middle Ages, wars and natural disasters to medieval scholarly rivalry leading to the manuscripts being destroyed, and lack of preservation over the centuries. Thousands of original manuscripts also remain to be catalogued in many libraries and some have yet to be located. Experts say there are as many as 5 million manuscripts and only about 60,000 of them have been edited.

Fortunately, copies and translations of the manuscripts have been preserved diligently over the centuries in many libraries such as the British Library (London), Topkapi Palace Museum Library (Turkey), Suleymaniye Library (Turkey), National Library of Medicine (USA), Princeton University Library (USA), Vatican Library, Leiden Library (Holland) and Cambridge and Oxford University Libraries (UK).

Home

On the Coffee Trail

'Abd al-Kadir b Muhammad al-Ansari al-Djaziri: *'Umdat al Safwa fi hill al kahwa*. Partly ed. in De Sacy, *Chrestomathie Arabe*, 2nd edn, Paris, 1826.

'Abd al-Kadir b Shaykh b al-'Aydarus: *Safwat al Safwa fi bayan hukm al-kahwa*. MS Berlin, Ahlwardt, Verzeichnis, No 5479.

Clocks

Al-Jazari. *Al Jami' bayn al-'Ilm al Nafi' wa sina'at al-Hiyal*, or *The Book of Knowledge of Ingenious Mechanical Devices*. Suleymaniye Library, Ayasofya 3606. The Metropolitan Museum of Art, New York, USA has a page of this book. The page is called 'Kitab fi ma'rifat al-hiyal al-handasiyya' and was written in Syria. It is from the Mamluk period and is dated 1315. The original book was written in 1206.

Al-Jazari: *Texts and Studies*. Collected and reprinted by Fuat Sezgin in collaboration with Farid Benfeghoul, Carl Ehrig-Eggert, Eckhard Neubauer. Frankfurt am Main: Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 2001.

Taqi al-Din: *Al-Kawakib al-durriyya fi al-bengamat al-dawriyya*, or *Pearl Stars on Cyclic Water Clocks*. Cairo, Dar al-Kutub, Miqat 557/1.

Taqi al-Din: *Alat al-rasadiya li Zij al-shahinshahiyya*. Library of the Topkapi Palace Museum, Hazine 452.

Taqi al-Din: *Rayhanat al-ruh fi rasm al-sa'at 'ala mustawi'l-sutuh*. Vatican Library 1424.

Tekeli, Sevim: *The Clocks in the Ottoman Empire in the 16th Century and Taqi al-Din's 'The Brightest Stars for the Construction of the Mechanical Clocks'*. Ankara 1966.

Chess

Al-Hanbali. *Kitab al-numuthaj al-qital fi la'b al-shatranj*, or *The Book of the Examples of Warfare in the Game of Chess*.

Al-Suli. *Kitab al-shatranc*, or *Muntahab Kitab al-shatranc*. Suleymaniye Library, Lala Ismail 560.

Al Suli: *Kitab al-shatranj*. Pub. by Fuat Sezgin. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1986.

Cleanliness

Al Kindi: *Kitab Kimiya' al-'itr wa'l-tas'idat*, or *Book of the Chemistry of Perfume and Distillations*. German translation, entitled *Buch über die Chemie des Parfüms und die Distillationen*, by K Garbers, Leipzig 1948.

Al Zahrawi: *Al-Tasrif li man 'ajiza 'an al-ta'lif* or *Al-Tasrif*, or *The Method of Medicine* or *The Arrangement of Medicine*. Suleymaniye Library, Hacibesir 502, and Khizana al-Hasaniyya, Rabat 134.

Al Zahrawi: *Texts and Studies I*. Ed. by Fuat Sezgin; pub. by Mazen Amawi, Carl Ehrig-Eggert, Eckhard Neubauer. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1996.

Trick Devices

Banu Musa Brothers: *Kitab al-hiyal al-Handasiyah*, or *The Book of Ingenious Mechanical Devices*. Vatican Library 317/1, Cairo (Taymur Sina'a 69).

Banu Musa Brothers: *Kitab al-hiyal of Banu Musa b Shaker*. Ed. by Ekmeleddin Ihsanoglu, pub. by Atilla Bir.

Al Jazari: *Al-Jami' bayna al-ilm wa-al amal al-naf fi sinaat al-hiyal*, or *The Book of Ingenious Devices*. Halab: Masadir wa-dirasat fi tarikh al-ulum al-Arabiyah al-Islamiyah. 2. Jamiat Halab. Mahad al-Turath al-Ilmi al-Arabi, 1979.

Vision and Cameras

Ibn al-Haitham: *Kitab al-Manazir*, or *Book of Optics*, known in Latin as *De aspectibus*, or *Perspective*. Suleymaniye Library, Ayasofya 2448. The Library of Congress, USA has a copy of this book. This 16th century copy is in Latin, entitled *Opticae thesaurus*. Library/Call Number QC353. A3316.

The Optics of Ibn Al-Haytham. Trans. with introduction and commentary by A I Sabra. Studies of the Warburg Institute, vol. 40. London: Warburg Institute, University of London, 1989.

Kamal al-Din al-Farisi: *Tanqih al-Manazir li-Zawi'l-absar wa'l-Basair*. Suleymaniye Library, Ayasofya 2598.

Sound System

Al-Farabi: *Kitab al-Musiqi al-Kabir*, or *The Great Book of Music*. Istanbul, Koprulu Library 953.

Al-Farabi: *Kitab al-Musiqi al-Kabir*. Ed. by Eckhard Neubauer. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1998.

Safi al-Din al-Baghdadi al-Urmuwi: *Kitab al-Musiqi*. Vatican Library 319/3.

Carpets

Ibn Badis: *Umdat al-Kuttab wa 'Uddat Dhawi al-Albab*, or *Staff of the Scribes*, or 'Book of the Staff of the Scribes and Implements of the Discerning with a Description of the Line, the Pens, Soot Inks, Liq, Gall Inks, Dyeing, and Details of Bookbinding' in M Levey, *Mediaeval Arabic Bookmaking and its Relation to Early Chemistry and Pharmacology*. Transactions of the American Philosophical Society, New Ser., Vol. 52 No. 4 (1962), pp. 1–79. Copy of MS: Oriental Institute, University of Chicago A12060.

School

Schools

Al-Ghazzali: Ihya Ulum al-Din, or *The Revival of Religious Sciences*. Ed. by Badwi Tabana, 1957; New Delhi: pub. by Nusrat Ali Nasri for Kitab Bhavan, 1982. The Van Pelt Library, University of Pennsylvania, USA. Library Numbers 46143, 52276 and 65623.

Libraries

Al-Jahiz: *Al-Bayan wa'l-tabyin*, or *Eloquence and Elucidation*. Yale University Library, USA. Ed. by Hasan Sandubi, Adab al-Jahiz. Cairo, 1345–1346 (1926–1927).

Al Jahiz: *Al-Bayan wa'l-tabyin*. Ed. by Abdussalam [Muhammad] Harun, 4th edn, Cairo: Maktab al-Hanci, 1975.

Al Muqaddasi: *Ahsan al-Taqasim fi Ma'rifat al-Aqalim*, or *The Best Divisions for Knowledge of the Regions*. English translation by G S A Ranking and Rizkallah F Azoo. Bombay, 1897–1910. Re-ed. by Fuat Sezgin, 1989. Cambridge University Library, UK has an English copy of this book translated from Arabic. Library/Class Number 811.b.6.214.

Mathematics, Trigonometry and Geometry

Abu al-Wafa': *Kitab al-Handasa*, or *Book of Geometry*. Cambridge University Library, UK has a French copy of this book (Manuscript Persian no. 169, ancien fonds de la Bibliothèque impériale, par M F Woepcke). Library Number IX 12.59

Abu al-Wafa': *Kitab fima yahtaju ilayhi al-sani najara fi amal al-handasiyya*, or *On Those Parts of Geometry Needed by Craftsmen*. Suleymaniye Library, Ayasofya 2753.

Al-Baghdadi: *Kitab al-takmila fi ilm al-Hisab*, or *Book of Completion on the Science of Arithmetic*. Suleymaniye Library, Laleli 2708/1

Banu Musa Brothers: *Tahriru Kitabi Ma'rifat Misahat al-ashkal al-Basitat al-Kuriyya*. Istanbul, Koprulu Library, I. Kisim 930/14

Al-Biruni: *Kitab al-Athar al-Baqiyya 'an al-Qurun al-Khaliyya*, or *Chronology of Ancient Nations*, also known as *Vestige of the Past*. Suleymaniye Library, Ayasofya 2947, and Edinburgh University Library, UK.

Al-Biruni: *Kitab al-Athar al-Baqiyya 'an al-Qurun al-Khaliyya*, or *Chronologie orientalischer volker*. Ed. by Fuat Sezgin, pub. by C Eduard Sachau. Frankfurt: Institut fur Geschichte der Arabisch-Islamischen Wissenschaften, 1998.

Al-Biruni: *Kitab Maqalid ilm al-hay'a la trigonometrie spherique chez les arabes de l'est a la fin du X siecle*, or *Kitab maqalid ilm al-hay'a*. Ed. by Marie Therese Debarnot. Damas: Institut Français de Damas, 1985.

Al-Farabi: *Maqala fi Ihsa al-Ulum*, or *The Book of the Enumeration of the Sciences*. Istanbul, Koprulu Library, Koprulu 1604/1.

Al-Farabi: *Maqala fi Ihsa al-Ulum*, or *Catalogo de las ciencias*. Ed. y traduccian castellana por Angel Gonzalez Palencia. Madrid: Universidad. Facultad de Filosofia y Letras, Publicaciones. Madrid: Imp. de Estanislao Maestre, 1932.

Ibn Sina: *Risala dar Handasa*, or *Treatise on Geometry*. Calcutta (cuz. 394–565).

Al-Karaji: *Al-Fahri fi'l Jabr wa'l Muqabala*. Istanbul, Suleymaniye Library, Husrev Pasa 257/7

Al-Khwarizmi: *Kitab al-Mukhtasar fi'l Hisab al-Jabr wal Muqabala*, or *Compendious Book of Calculation by Completion and Balancing*. Medina, Hikmat jabr 4, 6. Princeton University Library, New Jersey, USA has a copy of this book. It contains algebra, integration, simple equations, surveying and testamentary regulations for divisions of inheritances.

Al-Siddiqi: *Risala fi'l-handasa*, or *Treatise of Geometry*. Suleymaniye Library, Ayasofya 2736.

Al-Tusi: *Al-Jabr wa'l-Muqabala*. Vatican Library 317/2.

Umar al-Khayyam: *Risala fi'l barahin 'ala masa'il al-jabr wa'l muqabala*, or *Treatise on Proofs of Problems of Algebra and Balancing*. Cairo, Riyada 898/3. Columbia University Library, USA also has a 13th-century copy from Lahore.

Umar al-Khayyam: *Mushkilat al-Hisab*, or *Problems of Arithmetic*. Leiden 199

Chemistry

Jabir ibn Hayyan: *Kitab al-Sab'in*, or *Book of Seventy Treatises on Alchemy*. Istanbul University Library, AY 6314. This book

contains: 'Al-Khawass al-Kabir', or 'Great Book of Chemical Properties', 'Al-Mawazin', or 'The Weights and Measures', 'Al-Mizaj', or 'The Chemical Combination', and 'Al-Asbagh', or 'The Dyes'.

Jabir ibn Hayyan: *Kitab fi al-Kimiya'*. Vatican Library 1485/1.

Al-Kindi: *Kitab Kimiya' al-'itr wa't-tas'idat*. See 'Cleanliness' section.

Al-Razi: *Kitab al-Asrar*, or *The Book of the Secret of the Secrets*. Istanbul University Library, Sarkiyat E., 77, and the National Library of Medicine, USA, MS A 33 item 9. It contains a description of laboratory equipment.

Story Corner

Ibn Tufayl: *Hayy ibn Yaqzan*, or *Alive, Son of Awake*. Cambridge University Library, Call Number, BENSLY 5.e.91, printed in Egypt.

Ibn Tufayl: *Hayy ibn Yaqzan*. Ed. by A. Amin (1952); trans. by L.E. Goodman. New York: Twayne Publishers, 1972.

Market

Agricultural Revolution

Ibn al-Awwam: *Kitab al-Filaha*, or *Book of Agriculture*. Istanbul University Library, TY 5823 and Library of the Topkapi Palace Museum, Hazine 429. There is also a French copy in the Library of Congress, USA, entitled *Le livre l'agriculture d' Ibn Awam*. Library/Call Number S.493.I.1814.

Ibn al-Awwam: *Kitab al-Filaha* or *Le livre de lagriculture*. Ed. by Fuat Sezgin, traduit de l'Arabe par J.J Clement-Mullet. Frankfurt am Main: Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 2001.

Ibn Vahshiyya: *El-Filahatu'n-nebatiyye*, or *L'agriculture nabateenne*. Ed. by Tavfik Fahd. Damascus: Institut Français de Damas, 1995.

Kusami: *Filahatu'n-Nabatiyye*, or *The Book of Nabatean Agriculture*, vols. I-VII. Ed. by Fuat Sezgin. Frankfurt: Institut fur Geschichte der Arabisch-Islamischen Wissenschaften, 1984.

Al-Masudi: *Muruj al-dhahab wa Ma'adin al-Jawhar*, or *The Meadows of Gold and Quarries of Jewels*. Sakarya University, Ilahiyat Faculty Library, 193. The Library of Congress, USA also has a copy. Library/Call Number D17.M32.

Al-Masudi: *Muruj al-dhahab wa Ma'adin al-Jawhar*, vols. I-VI. Ed. by Muhammad Muhyiddin Abdulhamid. Al-Maktaba al-Ticarat al-Kubra, 1964.

Farming Manuals and Ecological Balance

Ibn al-Awwam: *Kitab al-Filaha*. See 'Agricultural Revolution' section.

Water Management

Al-Karaji: *Kitab Intibat al-miyah al-khafiyyat*, or *Extraction of Underground Waters*. India, Patna, Oriental Public Library at Bankipore, 2468/32.

Al-Maqrizi: *Kitab al-Suluk li Ma'rifat Duwal al-Muluk*, or *Book of Entrance to the Knowledge of the Dynasties of the Kings*. Pub. by Said A.F. Ashour. Cairo: Matba'at Dar al-Kutub, 1970. The Library of Congress, USA has a 19th century copy of this book, entitled Al-Tibr al-Masbuk fi Dhayl al-Suluk. Library/Call Number DT96.S25 1897.Arab.

Al-Nuwayri: *Nihayat al-Arab fi Funun al-Adab*, or *The Arab Art of Manners*. Cairo: Dar al-Kutub al-Misriyah, 1923.

Raising Water

Al-Jazari: *Al-Jami' bayn al-'Ilm al-Nafi' wa sinaat al-Hiyal*. See 'Clocks' section.

Taqi al-Din: *Turuq al-Saniyya fi al-Alat al-Ruhaniyya*, or *The Sublime Methods of Spiritual Machines*. Cairo, Dar al-Kutub, Miqat 4.

Dams

Al-Idrisi: *Nuzhat al-Mushtaq fi 'khtirak al-Afaq* or *Al-Kitab al-Rujari*, or *A Recreation*

for the Person who Longs to Traverse the Horizons or *Book of Roger.* Suleymaniye Library, Husrev Pasa 318. Rome 1592, re-ed. by Fuat Sezgin, 1992. A copy is found at The Narodna Biblioteka Sv. Sv. Kiril i Metodii (NBKM), Sherif Khalil Pasha Collection St Cyril and St Methodius National Libraries, Bulgaria.

Windmills

Al-Masudi: *Muruj al-dhahab wa Ma'adin al-Jawhar.* See 'Agricultural Revolution' section.

Trade

Ibn Hawqal: *Kitab al-Masalik wa-al-Mamalik*, or *The Book of the Routes of the Kingdoms*, or *Opus geographicum auctore Ibn Haukal (Surat al-ard).* Ed. by J H Kramers. 1-2. Lugduni Batavorum, 1938-1939; re-ed by Fuat Sezgin, 1992.

Commercial Chemistry

Ibn Badis: *'Umdat al-Kuttab wa 'Uddat Dhawi al-Albab.* See 'Carpets' section.

Al-Kindi: *Kitab Kimiya' al-'itr wa't tas'idat.* See 'Cleanliness' section.

Paper

Ibn Badis: *Umdat al-Kuttab wa 'Uddat Dhawi al-Albab.* See 'Carpets' section.

Ibn Hawqal: *Kitab al-Masalik wa al-Mamalik.* See 'Trade' section.

Pottery

Al-Maqrizi: *Kitab al-Suluk li Ma'rifat Duwal al-Muluk.* See 'Water Management' section.

Hospital

Hospital Development

Ibn Jubayr: *Rihlat Ibn Jubayr*, or *The Travels of Ibn Jubayr.* Yale University Library, USA. English copy. Library/Call number Fod41 Jb542 1852. Trans. from the original Arabic by R J C Broadhurst, with an introduction and notes. New Delhi: Goodword Books, 2001, c2003.

Ibn Sina: *Al-Qanun fi al-Tibb*, or *Code of Laws in Medicine*, referred to as the *Canon*. There are many old copies of this book in circulation. Suleymaniye Library, Hekimoglu 580. Copies (one in Latin) are also in Princeton University, New Jersey, USA. Library Numbers 1079, 1080, 1081, 1082 and 1083 are kept as a part of the Garrett Collection.

Al-Khujandi: *Al-Talwih li Asrar al-Tanqih*, or *Tanqih al-Maknun.* Vatican Library 305.

Instruments of Perfection

Ibn Zuhr: *Kitab al-Taisir fi al-Mudawat wa al-Tadbir* or *Book of Simplification Concerning Therapeutics and Diet.*

Al-Zahrawi: *Al-Tasrif li-man 'ajiza 'an al-taalif.* See 'Cleanliness' section.

Surgery

Ibn al-Quff: *Kitab al-'Umda fi sina'at al-jiraha*, or *The Foundation.* Suleymaniye Library, Hekimoglu 579. The Wellcome Trust Library, London, UK has a copy of this book which has been translated as *A Pillar in the Art of Surgery.* Library Number Wellcome MS Arabic 431.

Ibn al-Quff: *Al-Shafi fi al-Tibb.* Vatican Library, Appendice 183.

Ibn Sina: *Al-Qanun fi al-Tibb.* See 'Hospital Development' section.

Al-Razi: *Kitab Al-Hawi*, or *Liber continens.* Library of the Topkapi Palace Museum, Ahmed III 2125. The National Library of Medicine, USA also has a copy. It is the oldest manuscript kept by the library and the third oldest Arabic medical manuscript known so far. The book is dated 1094 CE. Library Number MS A17f.

Al-Zahrawi: *Al-Tasrif li-man 'ajiza 'an al-taalif.* See 'Cleanliness' section.

Blood Circulation

Ibn Nafis: *Sharh Tashrih al-Qanun*, or *Commentary on the Anatomy of the Canon of Avicenna.* Suleymaniye Library, Fatih 3626. The National Library of Medicine, USA has two copies of this book. Library Numbers MS A 21 and MS A 56.

Ibn Sina: *Al-Qanun fi al-Tibb*. See 'Hospital Development' section.

Ibn Sina's Bone Fractures

Ibn Nafis. *Sharh Tashrih al-Qanun*. See 'Blood Circulation' section

Ibn Sina, *Al-Qanun fi al-Tibb*. See 'Hospital Development' section

Ibn Sina: *Kitab al-Shifa'*, or *The Book of Cure, Healing or Remedy from Ignorance*. Library of the Topkapi Palace Museum, Ahmed III 3261. The University of Michigan, Near East Division, USA has some parts of a copy of this book, entitled al-Tabi'iyyat (al-Shifa')'. This Arabic copy covers Islamic philosophy, and part of Ibn Sina's *al-Shifa'*. It contains the following sections: book 2, *al-Sama' wa al-'alam* (on the heavens and the earth); book 3, *Ilm al-Nabat* (on plants); book 6, *Kitab al-nafs* (on the soul); book 8, *al-Hayawan* (on animals). Library/Call Number Heyworth-Dunne manuscript No. 65.

Ibn Sina: *Avicenna's De Anima: Being the Psychological Part of Kitab al-Shifa, or Kitab al-Shifa: al-fann al-sadis min al-tabiyyat wa huwa kitab al-nafs*. Ed. by Fazlurrahman, 3rd edn. University of Durham, 1970.

Al-Majusi: *Kamil al-Sinaa al-Tibbiyya*. Library of Topkapi Palace Museum, Ahmed III nr. 2060. Vatican Library 314.

Notebook of the Oculist

Abu al-Farag (Bar Hebraeus) *The Abridged Version of 'The Book of Simple Drugs' of Ahmad Ibn Muhammad Al-Ghafiqi*. Trans. and ed. by M Meyerhof, G P Sobhy; re-ed. by Fuat Sezgin. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1996.

Al-Ghafiqi: *Al-Murshid fil al-kuhl*, or *The Right Guide in Ophthalmic Drug*. Barcelona: Laboratoires du Nord de l'Espagne, 1933.

Al-Ghafiqi. *Texts and studies*. Ed. by Fuat Sezgin; pub. by Mazen Amawi, Carl Ehrig-Eggert, Eckhard Neubauer. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1996

Ibn Isa: *Tadhkirat al-Kahhalin*, or *Memorandum Book for Ophthalmologists* or *Notebook of the Oculist*. Vatican Library 313. Trans. into German by J Hirschberg and J Lippert (Leipzig, 1904), and into English by C A Wood (*The Tadhkirat of Ali ibn Isa of Baghdad. Memorandum Book of a 10th Century Oculist*. Northwestern UP, Chicago, 1936).

Ibn Nafis. *Al-Muhaddid fi tibb al-Ayn*. Vatican Library 307

Herbal Medicine

Al-Dinawari: *Kitab al-Nabat*, or *The Book of Plants*. Ed. by Bernhard Lewin. Uppsala Wiesbaden: A B Lundequistska Bokhandeln 1953.

Al-Ghafiqi: *Kitab al-adwiya al-Mufrada*, or *The Book of Simple Drugs*. Cairo: Egyptian University, 1932–40

Al-Ghafiqi. *Kitab jami' al-Mufradat*, known as *Materia Medica*. The Bodleian Library, Oxford, UK has a copy of this book. Abridged by Bar Hebraeus; ed. by Max Meyerhof and George P G Sobhy. Cairo: Cairo Medical Faculty, 1937–38

Ibn al-Baytar: *Kitab-al-Jami fil Adwiya al-Mufrada*, or *Dictionary of Simples Remedies and Food*. Suleymaniye Library, Damad Ibrahim 929. The Wellcome Trust Library, London, UK has a copy of this book. It is dated 18th century. Library Number Wellcome MS Arabic 429

Ibn Samajun. *Jami al-adwiya al-Mufrada*, or *Collection of Simples, Medicinal Plants and Resulting Medicines*. Pub. by Fuat Sezgin. Frankfurt am Main: Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 1992.

Pharmacy

Al-Biruni: *Kitab al-Saydana fi'l-tib*, or *Book of Medicines* or *Book of Pharmacology*. Suleymaniye Library, Izmirli I. 4175. Ed. and pub. with English translation by Hakim Mohammad Said, introduction,

commentary and evaluation by Sami K Hamarneh, 1 2, Karachi, 1973.

Al-Harawi. *Kitab al-Abniya 'an haqa'iq al Adwiya, or the Foundations of the True Properties of Remedies.* Pub. by Fuat Sezgin. Frankfurt am Main: Institute for the History of Arabic Islamic Science at the Johann Wolfgang Goethe University, 1996.

Ibn al Baytar: *Kitab-al-Jami fil Adwiya al-Mufrada.* See 'Herbal Medicine' section.

Ibn al Wahid: *Kitab al-Adwiya, or The Book of Simple Drugs.* Pub. by Ahmad Hasan Basaj. Beirut, Lebanon: Dar al Kutub al Ilmiyah, 2000.

Ibn Sina: *Al-Qanun fi al-Tibb.* See 'Hospital Development' section.

Ibn Sina: *Kitab a Shifa'.* See 'Ibn Sina's Bone Fractures' section.

Al Kindi: *Aqrabadhin, or Medical Formulary.* Suleymaniye Library, Ayasofya 3603.

Al Razi: *Kitab al-Mansuri, or Liber almansoris.* The manuscript was written for the Iranian prince Abu Salih al Mansur ibn Ishaq in 903. The National Library of Medicine, USA has a copy of this book which has a diagram of ventricles of cells in the brain. The copy is dated 17th century Library Number MS A 28.

Al Zahrawi: Al Tasrif li man 'ajiza 'an al taalif. See 'Cleanliness' section.

European Medicine

Ibn al-Jazzar: *Zad al-Musafir, or The Guide for the Traveller Going to Distant Countries or Traveller's Provision,* known in Latin as the *Viaticum.* Trans. and ed. by Gerrit Bos. Pub. London and New York, Kegan Paul International, 2000.

Ibn al Thahabi: *Kitab al Ma'a, or The Book of Water.* A copy of the manuscript is kept in Tlemcen, Algeria.

Ibn Nafis: *Al Shamil fi al-Tibb, or Comprehensive Book on the Art of Medicine.* Istanbul, Koprulu Library, I. kisim, nr 987/1. Vatican Library 306. The National Library of Medicine, USA has a copy of this book, entitled *Kitab al Mujiz,* and *Kitab al Mujiz fil al Tibb,* or *The Complete Book on Medicine.* It may have been copied in the 17th century. It has a diagram of an eye and visual system and a diagram of diagnosis by pulse. Library Numbers MS A 43, MS A 44 and MS A 44.1

Al Majusi: *Al Kihalah (tibb al- uyun) fi Kitab Kamil al-sina'ah al tibbiyah al ma ruf bi-al-Malaki, or The Royal Book,* also known as the *Pantegni.* Pub. by Muhammad Zafir Wafa i, Muhammad Rawwas Qal ahi'ji. Damascus, Wizarat al Thaqafah, 1997. The Wellcome Trust Library, London, UK has two copies of this book. These are stored in the Haddad Collection. Library Numbers Wellcome MS Arabic 409 and 410.

Al-Zahrawi. *Al Tasrif li-man 'ajiza 'an al taalif.* See 'Cleanliness' section.

Bernard Quaritch (Firm): *Arabic Science and Medicine: A Collection of Manuscripts and Early Printed Books Illustrating the Spread and Influence of Arabic Learning in the Middle Ages and the Renaissance.* Bernard Quaritch catalogue 1186. London: Bernard Quaritch (1993?)

Town

Bookshops

Ibn al-Nadim: *Fihrist al Ulum, or The Catalogue or Index of the Sciences.* Suleymaniye Library, Sehid Ali Pasa 1934. A German copy is in the University of Michigan Library, Near East Division, Library/Call Number PJ7521.I13 N14 1871. English translation by Bayard Dodge. New York, Columbia University, 1970

Fabulous Fountains

Banu Musa brothers: *Kitab al hiyal al-Handasiyah.* See 'Trick Devices' section.

Public Baths

Ibn Battuta: *Al-Rihla, or The Journey.* Public Library of Cambridge has a 19th-century copy. Library Number 890.8 O7p no.1

World

Planet Earth

Al-Battani: *Kitab al-Zij al-Sabi'*, or *De scientia stellarum — De numeris stellarum et motibus*, or *The Sabian Tables*. Tunis, Zaytuna 2843. Cambridge University Library, UK has a Latin copy called *De scientia stellarum liber, cum aliquot additionibus Ioannis Regiomontani*. It was published in Bologna, 1645. Library/Call Number Adams.6.64.4. Al-Battani's *Kitab al-Zij al-Sabi* was trans. by C. A. Nallino, 1899–1907.

Al-Biruni: *Kitab fi ifrad al-Maqal fi amr al-azlal*, or *Shadows or Gnomonics*. India, Patna, Oriental Public Library at Bankipore, 2468/36.

Al-Biruni: *Al-Qanun al-Mas'udi fi'l-hay'a wa'l-nujum*, or *Mas'udic Canon on Astronomy and Astrology*. Suleymaniye Library, Carullah 1498.

Ibn Hazm: *Al-Fasl fil Millal wa al-ahwa wa'n-nihal*, or *Conclusion on the Nations*. Ed. by Muhammad Ibrahim Nasir, Abdurrahman Umayra. Jiddah: Maktabatu Ukaz, 1982. Cairo, 1–5, 1317–1321 h (1899–1903). Cambridge University Library, USA has a copy of this book. Library/Call number Moh.121.b.50.

Ibn Yunus: *Al-Zij al-Hakimi*, or *The Hakemite Tables* (not all of which seems to have survived). C. Caussin, 'Le livre de la grande table hakemite', in *Notices et extraits…* vii (1804), 16–240.

Al-Khujandi: *Risala fi tashih al-mayl wa 'ard al-balad*, or *Treatise on Determining the Declination and Latitude of Cities with More Accuracy*. Beirut, Greek Orthodox School Library 364/1.

Surveying

Maslama al-Majriti: *Rutbat Al-Hakim*, or *The Rank of the Wise*. Istanbul, Ali Emiri-Arabi, 2836/2.

Earth Science

Al-Biruni: *Kitab Al-Jamahir fi Ma'rifat al-Jawahir*, or *Treatises on How to Recognize Gems*. Library of the Topkapi Palace Museum, Ahmed III 2047. Ed by Fuat Sezgin. Frankfurt am Main: Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 2001.

Al-Biruni: *Al-Qanun al-Mas'udi fi'l-hay'a wa'l-nujum*. See 'Planet Earth' section.

Ibn Sina: *Kitab a-Shifa'*. See 'Ibn Sina's Bone Fractures' section.

Ikhwan al-Safa' (Brothers of Purity): *Rasa'il*, or *Epistles*. Vatican Library 1608/1. Princeton University Library, New Jersey, USA. Library Number 1129 (Garrett Collection).

Al-Kindi: *Risala fi anwa al-jawahir al-thaminah wa ghayriha*, or *Treatise on Various Types Of Precious Stones and Other Kinds Of Stones*.

The Letters (Rasa'il) of al-Kindi al-falsafiyya. Ed. by M. A. H. Abu Ridah. Cairo: Matbaatu Hassan, 1978.

Masawayh: *Kitab al-Jawahir wa-Sifatiha wa-fi ayyi Baladin Hiya, wa-Sifat al-Ghawwasin wa-al-Tujjar*, or *Gems and their Properties*. The Wellcome Trust Library, London, UK has a copy of this book, published in Cairo in 1936. It is also published by Abu Zaby: Al-Majma al-Thaqafi, c.2001. This book has been translated as *Dispersed Gems on Perfumes According to Their Properties and Quarries Where They Were Found*. Library Number Wellcome MS Arabic 468 (part of the Haddad Collection).

Natural Phenomena

Al-Biruni: *Al-Qanun al-Mas'udi fi'l-hay'a wa'l-nujum*. See 'Planet Earth' section.

Ibn al-Haitham: *Kitab al-Manazir*, or *Book of Optics*. See 'Vision and Cameras' section.

Ibn Hazm: *Al-Fasl fil Millal*. See 'Planet Earth' section.

Al-Kindi: *Risala fi'l-illa al-fa'ila li'l-madd wa'l-jazr*, or *Treatise on the Efficient Cause of the Tidal Flow and Ebb*. Oxford, Bodleian Library, I 877/12.

Al Kindi: *Risala fi 'illat al-lawn al-azraq alladhilu yura fi'l-jaww fi jihat al-sama*, or *Treatise on the azure colour which is seen in the air in the direction of the heavens and is thought to be the colour of the heavens.* Suleymaniye Library, Ayasofya 4832/2.

Geography

Al Bakri: *Kitab al Masalik wa'l Mamalik*, or *Book of Highways and of Kingdoms.* Cambridge University Library, UK has the original text of the book by Abu Ubayd Al Bakri (1040–1094). The book also contains translations in Latin and Polish, published in 1946. Library/Call number 590:01.b.17 1.

Al Biruni: *Alberuni's India: An Account of the Religion, Philosophy, Literature, Geography, Chronology, Astronomy, Customs, Laws, and Astrology of India about A.D. 1030, vol. I-II.* Trans. by Edward C. Sachau; ed. by Fuat Sezgin. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1993.

Al-Biruni: *The Determination of the Coordinates of Positions for the Correction of Distances Between Cities: A Translation from the Arabic of Al Biruni's kitab tahdid nihayat al amakin litashih masafat al-masakin.* Ed. by Fuat Sezgin, pub. by Mazen Amawi, Carl Ehrig Eggert, Eckhard Neubauer. Frankfurt: Institut für Geschichte der Arabisch Islamischen Wissenschaften, 1992.

Ibn al Nadim: *Fihrist'al Ulum.* See 'Bookshops' section.

Ibn Jubayr: *Rihlat Ibn Jubayr.* See 'Hospital Development' section.

Al Idrisi: *Nuzhat al Mushtaq fi 'khtirak al-Afaq.* See 'Dams' section.

Mahmud Kashgharli: *Divanu Lugat it Turk, or Compendium of Turkish Dialects.* Istanbul, 1915-1917.

Al Jahiz: *Kitab al-Buldan.* Baghdad: Matbaat al Hukumah, 1970.

Al Khwarizmi: *Kitab Surat al-Ardh min al-mudun wa'l jibal wa'l-bihar wa'l jaza'ir wa'l-anhar*, or *Book of Geography: A Picture Book of the Earth, Cities, Mountains, Seas, Islands, and Rivers* or *The Form of the Earth.* German translation entitled *Das Kitab Surat al ard, des Abu Ga'far Muhammad ibn Musa al-Khuwarizmi, herausg.* Unikum des Bibliotheque de l'Universite et Regionale in Strasburg (Cod. 4247) von Hans v. Mzik. Wina, 1345 h. –Wien 1926.

Al Muqaddasi: *Ahsan al-Taqasim fi Ma'rifat al Aqalim.* See 'Libraries' section.

Al-Ya'qubi: *Kitab al Buldan*, or *Book of Countries.* Istanbul University, Islam Arastirmalari Library, 1262, and Yale University Library, USA, Library/Call Number Geography Folio B4737.

Yaqut: *Mu'jam al Buldan*, or *Dictionary of Countries.* 1-5. Beirut, 1374-1376 h. (1955-1957). Cambridge University Library, USA has a copy of this book, dated 1906 and published in Egypt. Library/Class number Moh.280.b.1

Maps

Al Idrisi: *Nuzhat al Mushtaq fi 'khtirak al-Afaq.* See 'Dams' section.

Piri Reis: *Kitab-i Bahriye*, or *The Book of Sea Lore* or *The Book of the Mariner* or *The Naval Handbook.* Ed. by Ertugrul Zekai Okte; transcription Vahit Cabuk, Turkish text Vahit Cabuk, Tulay Duran, English text Robert Bragner. Ankara: Culture and Tourism Ministry, 1988. Istanbul, Koprulu Ahmed Pasa, 171, 172.

Travellers and Explorers

Abu al-Fida': *Taqwim al Buldan*, or *Survey of Countries.* Library of the Topkapi Palace Museum, Ahmed III 2855. Bodleian Library, Oxford, UK has several copies of this book from the 18th century.

Al Biruni: *Tahdidu nihayat al-amakin li't-tashihi masafat al-masakin.* Ed. by Fuat Sezgin; pub. by Mazen Amawi, Carl Ehrig Eggert, Eckhard Neubauer. Frankfurt: Institut fur Geschichte der Arabisch Islamischen Wissenschaften, 1992.

Ibn Battuta. *Al Rihla*. See 'Public Baths' section.

Ibn Jubayr: *Rihlat Ibn Jubayr*. See 'Hospital Development' section

Ibn Khurradadhbih. *Al-Masalik wal Mamalik, or Book of Roads and Provinces, or Le livre des routes et des provinces*. Ed. by Casimir Barbier de Meynard. JA (6). 5, 1865, 5–127; re-ed. by Fuat Sezgin, 1992. Cambridge University Library, USA has a copy of this book, dated 1889. Library/Class Number Moh.280.c.28

Al-Muqaddasi. *Ahsan al-Taqasim fi Ma'rifat al-Aqalim*. See 'Libraries' section.

Al-Yaqubi. *Kitab al-Buldan*. See 'Geography' section.

Yaqut. *Mu'jam al-Buldan*. See 'Geography' section.

Navigation

Al-Masudi. *Muruj al-dhahab wa Maadin al-Jawhar*. See 'Agricultural Revolution' section

Al-Qibjaqi. *Kitab Kanz al-Tujjar fi ma'rifat al-Ahjar, or The Book of Treasure for Merchants who Seek Knowledge of Stones*. The book was written in 1282 and dedicated to Sultan Qalaun. It is referred to and discussed in B A Rosenfeld and E Ihsanoglu, *Mathematicians, Astronomers and Other Scholars of Islamic Civilisation and their Works (7th-19th c.)*. Istanbul IRCICA, 2003, No. 649

Piri Re'is. *Kitab-i-Bahriye*. See 'Maps' section.

Weaponry

Ibn Aranbugha al-Zardkash: *Armoury Manual*. Ed. by Fuat Sezgin. Reproduction from MS Istanbul, Library of the Topkapı Palace Museum, Ahmed III 3469 (fols. 35a–59a). Frankfurt am Main, Institute for History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 2004.

Al-Rammah. *Kitab Al-Furusiyya wa Al-Manasib Al-Harbiyya, or The Book of Horsemanship and Ingenious War Devices*. It is also called *Tuhfat al-Mujahidin fi al-Amal bi'l-Mayadin*. Suleymaniye Library, Ayasofya 3799 and Nuruosmaniye Library 2294

Omerî: *A Muslim Manual of War, or Tafrij al-kurub fi tadbir al-hurub*. Ed. and trans. by George T Scanlon. Cairo: The American University at Cairo, 1961.

Social Science and Economy

Ibn Khaldun: *Al-Muqaddimah, or the Introduction*. Istanbul University Library, Arabic, 2743, 835. The Library of Congress, USA also has a copy. Library/Call Number D.16.7.I23 1879

Ibn Khaldun. *The Muqaddimah, an Introduction to History*. Ed. by N J Dawood; trans. by Franz Rosenthal. London: Routledge and Kegan Paul, 1978.

Post and Mail

Al-Nuwayri: *Nihayat al-Arab fi Funun al-Adab*. See 'Water Management' section

Universe

Astronomy

Al-Battani: *Al-Zij al-Sabi*. See 'Planet Earth' section

Al-Biruni: *Kitab al-Tafhim li-awa'il sinaht al-tanjim, or The Book of Instruction in the Elements of the Art of Astrology*. Ed. by Fuat Sezgin; trans. by R. Ramsay Wright. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1998.

Al-Farghani. *Kitab fi Harakat al-Samawiyyah wa Jawami Ilm al-Nujum, or Compendium of Astronomy*. Suleymaniye Library, Ayasofya 2843/2.

Al-Farghani and Al-Battani: *Texts and Studies*. Collected and Reprinted by Fuat Sezgin in collaboration with Mazen Amawi, Carl Ehrig-Eggert, Eckhard Neubauer. Frankfurt. Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1998

Ibn al-Shatir al-Muwaqqit: *Kitab Nihayat al-sul fi Tashih al-Usul, or Limit of Desire in Correcting Principles*. Cairo, Teymur riyada 154.

Ibn Rushd: *Tahafut al-Tahafut*, or *The Incoherence of the Incoherence*. Pub. in Cairo, 1303 h (1886).

Ibn Yunus: *Al-Zij al-Kabir al-Hakimi*, or *the Hakemite Tables*. See 'Planet Earth' section.

Al-Zarqali: *Kitab al-a'mal bi'l safiha al Zijyya*, or *Book of Operations by Means of Tympanum of Zijes*. Suleymaniye Library, Esad Efendi 2671/1.

Observatories

Abu Mansour: *Al-Zij al-Mumtahan*, or *The Verified Tables*. Spain, Escorial, Library of the St Laurentius Monastery, II, 927

Astronomical Instruments

Al-Battani: *Al-Zij al-Sabi*. See 'Planet Earth' section.

Al-Halabi: *Bughyat al-Tulab fi'amal bi'l rub al-astrulab*, or *Aims of Pupils on Operations with the Quadrant of Astrolabe*. Leiden, University Library 1001/8

Al-Hamawi: *Ad-Durr al-Gharib fil amal bi dairat al-tayyib*, or *Rare Pearls on Operations with the Circle for finding Sines*. Leiden, University Library 187b/4

'Izz al-Din al-Wafa'i: *Al-Nujum al-Zahirat fi amal bi'l rub al-Muqantarat*, or *Brilliant Stars on Operations with the Almucantar Quadrant*. Suleymaniye Library, Fatih 3448

Jabir ibn Aflah: *Kitab al-Hai'a*, or *Book of Cosmology*

Jabir ibn Aflah: *Islah al-Majisti*, or *Correction of the Almagest of Ptolemy*. Berlin, Staatsbibliothek - State Library 5653.

Al-Khujandi: *Al-Talwih li-Asrar al-Tanqih*. See 'Hospital Development' section.

Shihab al-Din al-Hamawi: *Masail Handasya*, or *Geometrical Problems*. Cairo, Riyada 694

Al-Sufi: *Suwar al-Kawakib al-Thabit*, or *Book of Fixed Stars*. A 17th-century Arabic copy is kept at Suleymaniye Library, Fatih 3422, and the Library of Congress, USA.

Taqi al-Din: *Turuq al-Saniyya fi al-Alat al-Ruhaniyya*. See 'Raising Water' section.

Astrolabe

Al-Biruni: *Al-Istiab fi San'at al-Usturlabe*. Turkey, Diyarbakir Public Library, 403/3.

Al-Bitruji: *Kitab al-Hayah* or *Kitab al-murta'ish fi'l-haya*, or *Book of Cosmology*. Library of the Topkapi Palace Museum, 3302/1. A 16th-century Latin translation of the manuscript is kept at Cambridge University Library, UK.

Al-Farghani: *Kitab fi san'at al-astrolabe*. Turkey, Kastamonu Public Library, 794-5.

Al-Farghani: *Kitab fi Harakat al-Samawiyah wa Jawami Ilm al-Nujum*. See 'Astronomy' section.

Ibn Isa: *Risala fi al-Usturlab*. Vatican Library, Codici Borgiani Arab, 217/3

Jamal al-Din al-Tariqi: *Risala fi ma'rifat al-Taqwim wa ma'rifat al-usturlab wa mawaqit wa 'ilm ahkam al-Nujum*. Vatican Library 1398/3

Masha'Allah: *Al-Kitab al-ma'ruf bi'l sab' wa 'l-ishrin*, or *The Book Known as Twenty-Seventh*, or *De scientia motus orbis*, *Massahalae de scientia motus orbis*. Norimbergae, 1504; and *Massahallae de elementis et orbibus coelestibus*. Norimbergae, 1549

Masha'Allah: *Kitab san'at al-asturlabat wa'l-'amal biha*, or *Book on the Construction of Astrolabes and their Operations*, or *De compositione et utilitate astrolabii*.

Al-Zarqali: *Kitab al-a'mal bi'l-safiha al-Zijyya*. See 'Astronomy' section.

Armillary Sphere

Dawud ibn Sulayman: *Kitab dhat al-halaq*, or *Book on the Armillary Sphere*. Cairo, Miqat 969/1a.

Jabir ibn Aflah: *Islah al-Majisti*. See 'Astronomical Instruments' section

Lunar Formations

Abu al-Fida': *Mukhtasar Tarikh Al-Bashar*, or *Concise History of Humans*. Turkey, Corum Hasan Pasa Public Library 1178.

Abu al-Fida': *Taqwim al-Buldan*. See

'Travellers and Explorers' section.

MashaAllah: *Al-Kitab al-ma'ruf bi'l-sabi' wa-'l-ishrin*. See 'Astrolabe' section.

MashaAllah: *Kitab sanat al-asturlabat wa'l 'amal biha*. See 'Astrolabe' section.

Al-Sufi: *Suwar al-Kawakib al-Thabit*. See 'Astronomical Instruments' section.

Al-Tusi: *Tarcama-i Kitab-i Suwar al-kawakib*. Suleymaniye Library, Ayasofya 2595.

Al-Tusi: *Al-Tadhkira fi al-Hay'a*. Vatican Library 319/1.

Ulugh Beg: *Al-Zij*, or *Astronomical Tables*. Suleymaniye Library, Ayasofya 2692.

Stars

Al-Sufi: *Suwar al-Kawakib al-Thabit*. See 'Astronomical Instruments' section.

Flight

Al-Firdawsi: *Shahnameh*, or *Book of Kings*. Ankara National Library, B 530. The Bodleian Library, Oxford, UK has a copy of this book, dated from the 15th century. There was another 17th-century copy for sale at Bonhams Auctions, London, UK on 6 April 2006. It remains with the private seller.

Ibn Jubayr: *Rihlat Ibn Jubayr*. See 'Hospital Development' section.

Further Reading

Home

BBC 2 (16 February 2004) *What the Ancients Did for Us: The Islamic World*

Channel 4 TV (5–19 August 2005) *An Islamic History of Europe*

Ellis, John (1774) *An Historical Account of Coffee with an Engraving, and Botanical Description of the Tree. To Which are Added Sundry Papers Relative to Its Culture and Use, as an Article of Diet and of Commerce*. Edward Dilly and Charles Dilly, London.

Friedman, D and Cook, E, *A Miscellany*. www.daviddfriedman.com/Medieval/miscellany_pdf/Miscellany.htm

Hart-Davies, Adam (2004) *What the Past Did for Us, A Brief History of Ancient Inventions*. BBC Books.

Lindberg, D C (1983) *Studies in the History of Medieval Optics*. Varorium, London

Lindberg, D C (1996) 'The Western Reception of Arabic Optics', in R Rashed (ed.), *Encyclopaedia of History of Arabic Science*. Routledge, London

Omar, S B (1977) *Ibn al-Haytham's Optics*. Bibliotheca Islamica, Chicago.

Ree, Hans (1999) *The Human Comedy of Chess*. Russell Enterprises.

Sopieva, Natasha (2001) *Ibn al-Haytham, the Muslim physicist*. www.MuslimHeritage.com.

School

Al-Ghazali, (2000 ed.), *Dear Beloved Son*, translated from Arabic by K. El Helbawy, Awakening UK, Swansea.

Burnett Charles (2005) *Leonard of Pisa (Fibonacci) and Arabic Arithmetic*. www.MuslimHeritage.com

Dodge, B (1962) *Muslim Education in Medieval Times*. The Middle East Institute, Washington DC.

Haskins, C H (1967) *Studies in the History of Mediaeval Science*. Frederick Ungar Publishing Co, New York.

Ihsanoglu, Ekmeleddin (2005) *Primary Schools under the Ottomans*. www.MuslimHeritage.com.

Mackensen, R (1934) 'Moslem Libraries and Sectarian Propaganda', in *The American Journal of Semitic Languages*, 1934–1935.

Makdisi, George (1980) 'On the origin and development of the college in Islam and the West', in Khalil I Semaan (ed.), *Islam and the Medieval West*. State University of New York Press.

Nakosteen, M (1964) *History of Islamic Origins of Western Education AD 800–1350*. University of Colorado Press, Boulder, Colorado.

Pedersen, J (1984) *The Arabic Book*. tr Geoffrey French. Princeton University Press, Princeton, New Jersey

Pinto, O (1929) 'The libraries of the Arabs during the time of the Abbasids', in *Islamic Culture 3*.

Ribera, J (1928) *Disertaciones Y Opusculos*. Two volumes, Madrid.

Sardar, Z and Davies, M W (1990) *Distorted Imagination*. Grey Seal Books, London.

Sarton, G (1927) *Introduction to the History of Science*. Three volumes. The Carnegie Institution, Washington.

Tibawi, A (1972) *Islamic Education*. Luzac and Company Ltd, London.

Watt, W M (1972) *The Influence of Islam on Medieval Europe*. Edinburgh University Press.

Wilds, E H (1959) *The Foundation of Modern Education*. Rinehart & Co, New York.

Zaimeche, Salah (2002) *Education in Islam. The Role of the Mosque*. Publication N° 4015, www.MuslimHeritage.com

Market

Artz, F B (1980) *The Mind of the Middle Ages*. Revised third edn, University of Chicago Press.

Channel 4 TV (5–19 August 2005) *An Islamic History of Europe*.

Bolens, L (1997) 'Agriculture', in Helaine Selin (ed.), *Encyclopedia of the History of Science, Technology, and Medicine in Non Western Cultures*. Kluwer Academic Publishers, Dordrecht/Boston/London.

De Vaux, Baron Carra (1921) *Les Penseurs de l'Islam*. Volume 2, Geuthner, Paris.

Hill, D R (1993) *Islamic Science and Engineering*. Edinburgh University Press.

Idrisi, Zohor (2005) *The Muslims Agricultural Revolution and its Influence on Europe*. Publication N° 4088, www.MuslimHeritage.com.

Le Bon, G (1884) *La Civilisation des Arabes*. IMAG, Syracuse, Italy.

Scott, S P (1904) *History of the Moorish Empire in Europe*. Three volumes, J B Lippincott Company, London.

Watson, A M (1983) *Agricultural Innovation in the Early Islamic World*. Cambridge University Press.

Zaimeche, Salah (2002) *A Review on Muslim Contribution to Agriculture*. Publication N° 4018, www.MuslimHeritage.com

Hospital

Channel 4 TV (5–19 August 2005) *An Islamic History of Europe*.

Burnett, Charles (2004) *Arabic Medicine in the Mediterranean*. www.MuslimHeritage.com

Campbell, D (1974) *Arabian Medicine, and its Influence on the Middle Ages*. Philo Press, Amsterdam.

FSTC (2001) *Pharmacology in the Making*. www.MuslimHeritage.com.

Ghalioungui, Paul (1970) 'Ibn Nafis', in *Studies in the Arabic Heritage*. The Ministry of Information of Kuwait.

Hirschberg, J, Lippert, J and Mittwoch, E (1905) *Die arabischen Lehrbucher der Augenheilkunde*, Abhdl. Der preussischen Akademie

Keys, T E and Wakim, K G (1953) *Contributions of the Arabs to Medicine* Volume 28, Proceedings of the Staff Meeting, Mayo Clinic.

Levey, M (1973) *Early Arabic Pharmacology* E J Brill, Leiden.

Lindberg, D C (1996) 'The Western Reception of Arabic Optics', in R Rashed (ed.), *Encyclopedia of History of Arabic Science*. Routledge, London.

Meyerhof, M (1935) 'Ibn Nafis and his theory of the lesser circulation', in *Isis*, volume 23.

Sarton, G (1927) *Introduction to the History of Science*. The Carnegie Institute, Washington.

Shaikh, Ibrahim (2001) *Who Discovered Pulmonary Circulation, Ibn al-Nafis or Harvey?* www.MuslimHeritage.com

Town

Channel 4 TV (5–19 August 2005) *An Islamic History of Europe*

Forbes, R J (1965) *Studies in Ancient Technology*. Volume 2, E J Brill, Leiden.

Frothingham, A W (1951) *Lustreware of Spain*. The Hispanic Society of America, New York.

Glick, T (1979) *Islamic and Christian Spain in the Early Middle Ages*. Princeton University Press, New Jersey

Harvey, J (1973) *The Master Builders* Thames and Hudson, London

Haskins, C H (1967) *Studies in the History of Mediaeval Science*. Frederick Ungar Publishing Co, New York.

Hobson, R L (1932) *A Guide to the Islamic Pottery of the Near East*. British Museum, London

Lambert, E (1958) *Art Musulman et Art Chretien dans la Peninsul Iberique*. Editions Privat, Paris

Lane, A (1947) *Early Islamic Pottery*. Faber and Faber, London.

Male, E (1928) *Art et Artistes du Moyen Age*. Libraire Armand Colin, Paris.

Saoud, R (2001) *Introduction to the Islamic City*. Publication N° 4012, www.MuslimHeritage.com

Wren, Christopher, the Junior (1750) *Parentalia: or, Memoirs of the Family of the Wrens, viz.* of Mathew Bishop. T Osborn and R Dodsley, London.

World

Alhabshi, Syed Othman (2001) *Mapping the World*. www.MuslimHeritage.com

Briffault, R (1928) *The Making of Humanity* George Allen, London.

Channel 4 TV (5–19 August 2005) *An Islamic History of Europe*

Fuat Sezgin in Zusammenarbeit mit Eckhard Neubauer. *Wissenschaft und Technik im Islam: Einführung in die geschihcte der Arabisch-Islamischen Wissenschaften*. (Vols. I–V) Frankfurt am Main. Institut fur Geschichte der Arabisch Islamischen Wissenschaften, 2003.

Ferber, S (ed.) (1975) *Islam and the Medieval West*. A Loan Exhibition (April 6–May 4) at the University Art Gallery, State University of New York

Glick, T (1979) *Islamic and Christian Spain in the Early Middle Ages*. Princeton University Press, New Jersey

Harley, J B and Woodward, D (eds.) (1992) *The History of Cartography, Volume Two, Book One: Cartography in the Traditional Islamic and South Asian Societies*. University of Chicago Press.

Holt, P M, Lambton A K S, and Lewis, B, eds. (1970) *The Cambridge History of Islam*. Volume 2, Cambridge University Press.

Kimble, G H T (1983) *Geography in the Middle Ages*. Methuen & Co Ltd, London

Roshdi, Rashed (ed.) (1996) *Encyclopaedia of the History of Arabic Science*. Routledge, London.

Scott, S P (1904) *History of the Moorish Empire in Europe*. Three volumes, J B Lippincott Company, London.

Watt, M (1972) *The Influence of Islam on Medieval Europe*. Edinburgh University Press, Edinburgh.

Zaimeche, Salah (2002) *A Review of Muslim Geography*. Publication N° 4013, www.MuslimHeritage.com.

Universe

Arnold, Sir Thomas and Guillaume, Alfred (1931) *The Legacy of Islam*. First edn, Oxford University Press.

Artz, F B (1980) *The Mind of the Middle Ages*. Third edn revised. University of Chicago Press.

BBC 4 (5–19 August 2005) *An Islamic History of Europe*.

Briffault, R (1928) *The Making of Humanity*. George Allen, London.

De Vaux, Baron Carra (1921) *Les Penseurs de l'Islam*. Volume 2, Geuthner, Paris.

Glubb, John (1969) *Short History of the Arab Peoples*. Hodder and Stoughton, London.

Hitti, P K (1970) *History of the Arabs*. Tenth edn, Macmillan and St Martin's Press, London.

Ronan, C (1983) 'The Arabian Science', in *The Cambridge Illustrated History of the World's Science*. Cambridge University Press.

Savage-Smith, Emilie (1992) 'Celestial Mapping', in J B Harvey and David Woodward (eds.), *The History of Cartography 2, Book 1*. University of Chicago Press.

Savory, R M (1976) *Introduction to Islamic Civilization*. Cambridge University Press.

Sayili, Aydin (2005) *Observatories in Islam*. www.MuslimHeritage.com, FSTC, republished from Dizer, M (ed.) International Symposium on the Observatories in Islam (19–23 September 1977) Turkey, Istanbul.

Sedillot, L A *Memoire sure les instruments astronomiques des Arabes*, which can be found in the British Library, St Pancras Reading Rooms, Ac 420/10.(1).

Bedini, Silvio A (1991) *The Pulse of Time*. Published by Leo S. Olschki, and found in the Biblioteca Di Nuncius.

Smith, D E (1953) *History of Mathematics*, Dover Publications, New York, Vol II.

Selin, Helaine (1997) *Encyclopaedia of the History of Science, Technology and Medicine in Non-Western Cultures*. Kluwer Academic Publishers, London.

Zaimeche, Salah (2002) *A Review on Missing Contribution to Astronomy*. Publication N° 4019, www.MuslimHeritage.com

A Thousand Years of Scholarship

BELOW IS SOME ESSENTIAL INFORMATION including names, birth and death dates, place of birth or work, and profession of many of the individuals mentioned in *1001 Inventions: Muslim Heritage in Our World*. This is for your reference, to help you place together a thousand years of scholarship and learning. The names in bold refer to how these people were commonly known, as many of the scholars, coming from distinguished families, had long names.

Abd al-Malik ibn Marwan (c.646–705); the fifth caliph who ruled from Damascus (685–705)

'Abd al-Rahman III (891–961); the caliph of Cordoba, Spain (912–961); a man of wisdom and patron of arts; founder of Madinat al-Zahra (a city now in ruins) on the outskirts of Cordoba

Yahya ibn **Abi Mansour** (9th century); Baghdad, Iraq; astronomer at the court of al-Ma'mun. He compiled the so-called *Al-Zij al-Mumtahan* or *The Validated Zij*

Abu Abdullah al-Bakri (1014–1094); Huelva, Spain; geographer and historian

Abu al-Fida' (1273–1331); Hama, Syria, geographer and astronomer

Abu al-Wafa', Mohammed al-Bouzjani (940–998); Buznaj, Baghdad, Iraq; mathematician, astronomer and geometrician

Ad-Dakhwar (early 13th century); Aleppo, Syria, physician at al-Nuri Hospital

Adelard of Bath (c.1080–c.1160); Bath, England; mathematician, philosopher

Albertus Magnus, also known as Albert the Great (1206–1280); Bavaria, Germany; scientist, philosopher and theologian

Alfonso X, also known as Alfonso the Wise (1221–1284), Spanish king of Castile and Leon (1252–1284); son and successor of Ferdinand III

Archimedes (287–212 BCE); Syracuse, Sicily, astronomer

Aristotle (383–322 BCE); Stagirus, Greece; philosopher

Roger Bacon (1214–1292); Ilchester, England, physicist, chemist and mathematician

Al-Baghdadi, real name: Abu Mansur Abr al-Qahir ibn Tahir ibn Muhammad ibn Abdallah al-Tamimi al-Shaffi, known as Ibn Tahir (980–1037); Baghdad, Iraq, mathematician

Banu Musa brothers (9th century), Baghdad, Iraq; Ibn Musa, Jafar Muhammad ibn Shakir (800–873); geometry and astronomy, Ibn Musa, Ahmed ibn Shakir (805–873), mechanics; Ibn Musa, Al-Hasan ibn Shakir (810–873); geometry

Al-Battani, Abu 'Abdallah Muhammad ibn Jabir, famously known as Albategnius (858–929); born in Harran, Turkey and worked in Baghdad, Iraq, astronomer and mathematician

Baybars, al-Malik al-Zahir Rukn al-Din Baybars al-Bunduqdari (1223–1277); Solhat, Turkey; Mamluk sultan who rose to power from being a slave, ruled Egypt and Syria (1260–1277); defeated the Mongols at Battle of Ayn Jalut

Al Biruni, Mohammed ibn Ahmed Abul Rayhan (973–1050), Harran, Turkey; mathematician, geographer, pharmacy, medicine, physics and earth science scholar.

Al Bitruji, Nur al-Din ibn Ishaq (d.1204), also known as Alpetragius, Morocco and Seville; astronomer.

Tycho Brahe (1546–1601); Skane, Denmark; astronomer and engineer.

Nicolaus **Copernicus**, Mikolaj Kopernik or Nicolaus Koppernigk (1473–1543); Thorn (Torun), Poland; astronomer and mathematician.

Al-Dimashqi (1256–1327); Damascus, Syria; traveller and explorer.

Al-Dinawari, Abu Hanifa (d.895); Andalusia, Spain; botanist.

Edward I (1239–1307); king of England (1272–1309); went on crusades to Acres (1271–1272); on his return he built castles on the Muslim plan, using the barbican design.

Queen Eleanor (1244–1290); Castile, Spain; daughter of Fernando III, king of Castile and Leon; she married King Edward I of England in 1254.

Euclid (325BC–265BC); Alexandria, Egypt; mathematician.

Al Farabi, Abu Nasr (870–950), also known as Alpharabius; near Farab, Khazakhstan but flourished and worked in Iraq; philosopher and music theorist.

Al Farghani, Abu al-Abbas Ahmad ibn Kathir, known as Alfraganus (d.861); Fargha-na, Transoxiana; astronomer and surgeon.

Muhammad **al-Fatih**, famously known as Mehmed II or al-Fatih (1432–1481); Adrianople, Thrace, Turkey; Ottoman sultan who ruled from Constantinople (1451–1481); conqueror of Constantinople.

Al Fazari, Abu Abdullah Muhammad ibn Ib-rahim (d.c.777); Kunduz, Afghanistan; mathematician, philosopher, poet and astronomer. The first Muslim astronomer to construct astrolabes.

Leonardo **Fibonacci** (1170–1250); Pisa, Italy; mathematician.

Fatima **Al-Fihri** (9th century); nicknamed Um al-Banin or 'the mother of children;' Fez, Morocco; art and building patron, founder of al-Qarawiyin University, Fez.

Al-Firdawsi, Abu al-Qasim Mansur (940–1020); Korasan, Iran; historian and chronicler.

Frederick II (1194–1250); king of Sicily (1198–1250); Roman Emperor (1220–1250).

Galen, Claudius (c.131–206); Pergamum, Greece; physician.

Gerard of Cremona (c.1114–1187); Lombardy, Italy; translator.

Al-Ghafiqi, Muhammad ibn Qassoum ibn Aslam (d.1165); physician, eye surgeon and herbalist.

Al-Ghazali, Abu Hamed, known in the West as Algazel (1058–1128); Khorasan, Iran; philosopher and theologian.

Al-Hakam I ruled Cordoba (796–823).

Al-Hakam II (915–978); Cordoba, Spain; son of Abderrahamn III; ruled al-Andalus from 961 to 978, famous for his library.

Ahmad **al-Halabi** (d.1455); Aleppo, Syria; astronomer.

Abu Bakr ibn al-Sarraj **al-Hamawi** (d.1328/9); Hama, Syria; geometer, astronomer and engineer.

Al-Hanbali, Taqi al-Din (1236–1328); Harran, Turkey; theologian, Quranic exegesis (*tafsir*), hadith and jurisprudence.

Abu Ishaq Ibrahim ibn Ishaq **al-Harbi** (d.285);

Baghdad, Iraq; prominent companion and theologian of the Hanbali School of Thought

Harun al-Rashid (766–809); the fifth Abbasid caliph, who ruled from Baghdad (786–809). He is famously known for his good relations with Charlemagne, to whom he sent a delegation with gifts including a hydraulic organ.

Hazarfen Ahmed Celebi (17th century); Istanbul, Turkey; pilot flying in 1638 from the Galata tower near the Bosphorus in Istanbul, landing on the other side of the Bosphorus.

Henry VIII (1491–1547); king of England (1509–1547), second son and successor of Henry VII.

Hippocrates (c.460–377 BCE); Kos island, Greece; physician.

Hunayn ibn Ishaq, al-'Ibadi (808–873); Baghdad, Iraq; member of the House of Wisdom; translator of Greek work into Arabic; physician.

Ibn Abi Usaybi'ah (d.1270); Damascus, Syria (practised in Egypt); chronicler of physicians and pharmacists; physician and oculist.

Ibn 'Aqil, Abu Al Wafa Ali (1040–1119); Baghdad, Iraq; theologian of the Hanbali School of Thought and humanist.

Ibn al-Awwam (12th century); Seville, Spain; agriculturist.

Ibn al-Baytar, Abu Muhammad Dia' al-Din Abdullah ibn Ahmad (1197–1248); Malaga, Spain; physician, herbalist, pharmacist and botanist.

Ibn al-Faqih, al-Hamadhani (10th century); Baghdad, Iraq; geographer and traveller.

Ibn al-Haitham, Abu Ali al-Hasan (965–1039), also known as Alhazen; Syria, Egypt; physicist and mathematician.

Ibn al-Hajj, Muhammad ibn Muhammad, Abu Abdullah (1258–1336); Fez, Morocco; educationalist and theologian.

Ibn al-Jazzar, Abu Ja'far Ahmad b Abi Khalid (c.855–955); Al-Qayrawn, Tunisia; physician.

Ibn al-Nadim, Abu al-Faraj Muhammad ibn Ishaq ibn Muhammad ibn Ishaq (10th century); Baghdad, Iraq; bibliographer and the author of the *Kitab al-Fihrist*; bookseller and calligrapher.

Ibn al-Quff, Abu'l-Faraj ibn Yacqub ibn Ishaq Amin al-Dawla al-Karaki (1233–1286); Damascus; physician.

Ibn al-Saffar, Abu al-Qasim Ahmed ibn Abdallah ibn Omar al-Ghafiqi, best known under the name of Ibn al-Saffar, meaning 'son of coppersmith' (d.1035); Cordoba, Spain; mathematician and astronomer.

Ibn al-Shatir al-Muwaqqit (1304–1375); Damascus, Syria; astronomer and timekeeper at the Umayyad Mosque of Damascus.

Ibn al-Thahabi, Abu Mohammed Abdellah ibn Mohammed al-Azdi (d.1033); Suhar, Oman; physician and encyclopaedist.

Ibn al-Wafid, Abu al-Mutarrif abd al-Rahman (1008–1074); also known as Abenguefit; Toledo, Spain; physician and pharmacologist.

Ibn Badis, al-Mu'izz (1007–1061); Tunisia; historian, scientist, chemist and ruler of North Africa (1016–1062).

Ibn Bajja, Abu Bakr Muhammad ibn Yahya ibn as-Say'igh, known as Avempace in the West (d.1138); Saragossa, Spain; philosopher and physician.

Ibn Bassal, Abu 'Abd Allah Muhammad ibn Ibrahim al-Tulaytuli (1085); Toledo, Spain; botanist, agriculturist and gardener.

Ibn Battuta, Abu Abdullah Muhammad (1304–1368/70); Tangier, Morocco; traveller, explorer and chronicler.

Ibn Fadlan, Ahmed (10th century), Baghdad, Iraq; explorer, traveller and chronicler

Ibn Firnas, 'Abbas (d.887); Korah, Takrna, Spain, humanitarian, technologist and chemist.

Ibn Hawqal, Abu Al Qasim Muhammad (920–990); Nisibis, Iraq; explorer, traveller and chronicler

Ibn Hazm, Abu Muhammad 'Ali ibn Ahmad ibn Sa'id (994–1064); Cordoba, Spain; theologian and man of letters

Ibn Isa, Ali (10th century); also known as Jesu Haly; Baghdad, Iraq, physician and oculist.

Ibn Jubayr, Abu al-Husayn Muhammad ibn Ahmad ibn Jubayr (12th century), Granada, Spain; traveller, explorer and chronicler

Ibn Juljul al-Andalusi (c.943), Cordoba, Spain; physician, herbalist and pharmacist

Ali **ibn Khalaf** al-Shakkaz (11th century), Toledo, Spain, an apothecary or herbalist, astronomer

Ibn Khaldun, Abd al-Rahman ibn Moham mad (1332–1406); Tunis, Tunisia, sociologist, historian, philosopher and economist.

Ibn Khurradadhbih (820–912), Baghdad, Iraq; geographer and director of the government postal service in Baghdad

Ibn Majid, Shihab al-Din Ahmed al-Najdi (1432–1437); Najd, Saudi Arabia; navigator.

Ibn Muqla, Abu Ali Mohammed (866–940); Baghdad, Iraq; Abbasid vizier, calligrapher, and one of the inventors of the *Naskhi* script.

Ibn Nafis, Abu Alhassan Alauldin Ali ibn Abi Hazm al-Qurashi (1210–1288), Damascus, Syria and flourished and worked in Cairo, Egypt, physician and discoverer of the circulation of the blood.

Ibn Rushd, Abu'l Walid Muhammad al Qurtubi, also known as Averroes (1126–1198); Cordoba, Spain; philosopher, physician, humanist and judge

Ibn Rustah, Ahmed (10th century), Isfahan, Iran; explorer and geographer

Ibn Sa'id al-Maghribi (1214–1274), Granada, Spain; historian, poet, traveller and geographer

Ibn Samajun (d.1002); Andalusia, Spain, herbalist, botanist and pharmacologist

Ibn Sarabiyun, Yuhanna, also known as Serapion (9th century); Syria, physician and pharmacist

Ibn Sina, also known as Avicenna (980–1037); Bukhara, Uzbekistan; physician, philosopher, mathematician and astronomer

Ibn Tufayl, Abu Bakr ibn Abd al-Malik ibn Muhammad ibn Muhammad ibn Tufayl al-Qaysi, also known as Abubar (d.1185); Granada, Spain; philosopher, physician and politician.

Ibn Tulun, Ahmad (835–884); originally was in the service of the Abbasid caliph and moved to become governor of Egypt as part of the Abbasid Caliphate. He built the famous Ibn Tulun Mosque in Cairo.

Ibn Yunus, Abu'l-Hasan Ali ibn Abd al Rahman ibn Ahmad al Sadafi (950–1009); Fustat, Cairo, Egypt; mathematician and astronomer who compiled the Hakemite Tables.

Ibn Zuhr, Abu Marwan (1091–1161); also known as **Avenzoar**; Seville, Spain; physician and surgeon.

Al-Idrisi (1099–1166); Ceuta (Morocco) and Palermo, Sicily; geographer and cartographer

Ikhwan al-Safa', also known as Brothers of Purity (c.983); Basra, Iraq; group of philosophers.

'Izz al-Din al-Wafa'i (d.1469); Cairo, Egypt; astronomer and mathematician.

Jabir ibn Aflah (1100–1145); Seville, Spain; mathematician and astronomer.

Jabir ibn Hayyan, Abu Musa, also known as Geber (722–815); Tus, Iran and lived and worked in Kufa, Iraq; chemist, druggist and physician.

Al-Jahiz, Abu Uthman Amr ibn Bahr (c.776–868); Basra, Iraq; philosopher and zoologist.

Al-Jazari, Badi'al-Zaman Abu al-'Izz Isma'il b.al-Razzaz (early 13th century); Diyarbakir, Turkey, engineer

Al-Jurjani, Abu Ruh Muhammad ibn Mansur ibn Abdullah (c.1088); Astarabad, Iran, oculist and surgeon.

Kamal al-Din, Abu'l Hasan Muhammad al-Farisi (1260–1319); Tabriz, Iran, mathematician and physicist.

Al-Karaji, Abu Bekr ibn Muhammad ibn al-Husayn, also known as al-Karkhi (953–1029); Baghdad, Iraq; mathematician and engineer. He wrote the *al-Fakhri*.

Al-Kashgharli, Mahmud (1073); Turkey; geographer and lexicographer.

Al-Kashi, Ghiyat al-Din (1380–1429); Kashan, Iran; mathematician and astronomer.

Johannes **Kepler** (1571–1630); near Stuttgart, Germany; mathematician and astronomer.

Al-Khujandi, Abu Mahmud Hamid ibn al-Khidr (940–1000); Khudzhand, Tajikistan; astronomer, built an observatory in Ray, Iran, and constructed a sextant.

Al-Khwarizmi, Muhammad ibn Musa (780–850); Khwarizm, Iran; mathematician, astronomer and geographer.

Al-Kindi, Abu Yusuf Yaqub ibn Ishaq al-Sabbah (801–873); Kufa, Iraq; cryptanalyst, mathematician, astronomer, physician and geographer, talented musician.

Al-Kuhi, Abu Sahl Wijan ibn Rustam (10th century), born in Kuh in Tabaristan, in North Iran but worked and flourished in Baghdad around 988, mathematician and astronomer.

Leonardo da Vinci (1452–1519); Venice, Italy, painter, draughtsman, sculptor, architect and engineer.

Mahmoud of Ghaznah, King (971–1030); ruled Afghanistan (998–1030).

Al-Majusi, 'Ali ibn al-'Abbas (10th century); Ahwaz, Iran, geographer.

Al-Ma'mun, Abu Jafar al-Ma'mun ibn Harun (786–833); one of the most enlightened Abbasid caliphs, who ruled from 813 until 833. He expanded the House of Wisdom.

Al-Mansur, Abu Jafar Abdullah ibn Muhammad Al-Mansur (712–775), Abbasid caliph who ruled from Baghdad (754–775), the founder of Baghdad in 762.

Al-Mansur, Yaqub (1160–1199); Marrakech, Morocco; Almohad sultan who ruled from Marrakech (1184–1199), succeeding his father Abu Yaqub Yuf, who ruled from 1163 until 1184.

Al-Maqrizi, Taqi al-Din Ahmad ibn 'Ali ibn 'Abd al-Qadir ibn Muhammad (1364–1442); Cairo, Egypt, historian.

Yahya ibn **Masawayh**, Abu Zakariah (776–857); Baghdad, Iraq, physician, pharmacologist, earth scientist and translator.

Masha'Allah (d.815), Cairo, Egypt, astronomer and mathematician.

Maslama ibn Ahmad **al-Majriti** (d.1007), Madrid, Spain; astronomer and mathematician.

Al-Masudi, Abul-Hassan Ali ibn Al Hussain (871–957); Baghdad, Iraq; explorer, geographer and historian.

Michelangelo di Lodovico Buonarroti (1475–1564); Tuscany, Italy; Italian Renaissance

sculptor, painter, architect and poet

Lady Mary Wortley Montagu (1689–1762); London, England, prominent member of society and wife of the British Ambassador to the Ottoman Empire

Al-Mawsili, Ammar ibn Ali (10th century), Mosul, Iraq, eye surgeon and ophthalmologist

Muhadhib ad-Din ibn an-Naqqash (d.1178); head of al-Nuri Hospital, chief physician of Sultan Muhammad.

Al-Mu'izz, Li-din Allah (930–975); a powerful Fatimid caliph who expanded the Fatimid rule from North Africa to Egypt; the founder of Cairo, al-Qahirah in 972/3 and the Mosque of al-Azhar

Al-Muktafi (d.908); Abbasid caliph who ruled from Baghdad (902–908).

Al-Muqaddasi, Muhammad ibn Ahmad Shams al-Din (945–end 10th century); Jerusalem; historian and geographer.

Al-Mutawakkil, Abbasid caliph who ruled from Samarra, Iraq (847–861), which was the short-lived Abbasid capital founded by his father al-Mu'tassim.

Muwaffaq, Abu al-Mansur (10th century); Herat, Afghanistan, pharmacist.

Nur al-Din ibn Zangi (1118–1174); sultan who ruled Aleppo and Damascus; built one of the earliest hospitals, al-Nuri Hospital

Al-Nuwayri, Abu al-Abbas Ahmad (1278-332), Cairo, Egypt; historian.

Offa, King (ruled 757–796); Mercia, England; one of the most powerful kings in early Anglo-Saxon England.

Palladio, Andrea (1505–1580); Padua, Italy architect and painter.

Piri Re'is, Ibn Haji Muhammad (1465–1554); Gallipoli, Turkey, sea admiral, geographer, explorer and cartographer.

Plato (427–347 BCE); Athens, Greece; philosopher.

Claudius Ptolemaeus, also known as **Ptolemy** (85–165 CE); Alexandria, Egypt; geographer and astronomer

Qalawun, Saif ad-Din al-Alfi al-Mansur (1222–1290); Mamluk sultan who ruled Egypt (1279–1290). In 1284, he built the famous and important al-Mansuri Hospital.

Al-Qazwini, Zakariya' ibn Muhammad (1203–1283); Qazwin, Iran; traveller, explorer and judge (*qadi*).

Baylak **al-Qibjaqi** (c.1282); Istanbul, Turkey; explorer, seafarer and geographer.

Qutb al-Din al-Shirazi (1236–1311); Shiraz, Iran; astronomer

Al-Rammah, al-Hassan Najm al-Din (c.1285), Syria; engineer and military historian.

Raphael, Raphaello (1483-1520); Urbino, Italy, painter and architect.

Al-Razi, Abu Bakr Muhammad ibn Zakariya (865–925); Ray, Iran, physician and chemist

Roger II (1093–1154); Palermo, Sicily, Norman king who ruled Sicily (1130–1154); son and successor of Roger I

Sabur ibn Sahl, also spelt Shapur (d.869); Jundishapur, Iran, physician and pharmacist

Saladin, Yusuf ibn Ayyub (1137–1193); Tikrit, Iraq; he led armies against the crusaders, defeating them in 1187 at Hattin; founded the Ayyubid dynasty and united Egypt and Syria.

Al-Samawal, Ibn Yahia al-Maghribi (d.1180); Baghdad, Iraq; mathematician and astronomer

Sayf al-Dawla, Abu al-Hasan ibn Hamdan (916–967); ruler of Aleppo and founder of the Hamadanid dynasty of Aleppo. He was famous for his patronage of scholars.

Michael Scott (c.1175–c.1236); Scotland, UK; physician, astrologer and translator.

Sibawaih (760–793); Bayza or Bayda, Iran; grammarian, considered the most important Arabic grammarian upon whose work all other Arabic grammars are based.

Sinan, Koca Mimar Sinan (1489–1588); Istanbul, Turkey; architect and designer.

Ibrahim ibn Sinan ibn Thabit ibn Qurra (908–946); Harran, Turkey; geometer, astronomer and mathematician.

Al-Sufi, 'Abd al-Rahman (903–986); Isfahan, Iran; astronomer.

Suleyman the Magnificent, also known as Suleyman II (1494–1566); one of the greatest sultans of the Ottoman Caliphate, who ruled from Constantinople (1522–1566).

Al-Suli, Abu Bakr Muhammad (10th century); great master of chess.

Pope Sylvester II, Gerbert of Aurillac (940/950–1003); Auvergne, France; Pope (999–1003), philosopher, mathematician and translator.

Umar ibn Farrukhan **al-Tabari**, also known as Omar Alfraganus (9th century); Tabaristan, Iran; astrologer; compiled the *Liber universus*.

Taqi al-Din al-Rasid, Muhammad ibn Ma'ruf al-Shami al-Asadi (c.1526–1585); Damascus, Syria; astronomer, engineer and mechanic.

Thabit ibn Qurra (c.836–901); Harran, Turkey; geometer, mathematician, astronomer and translator of Greek work into Arabic.

Al-Tusi, Nasir al-Din (1201–1274); Maragha (Tus), Khorasan, Iran; astronomer, mathematician and philosopher.

Ulugh Beg, Muhammed Taragai (1394–1449); Samarkand, Uzbekistan; astronomer.

Umar al-Khayyam, Ghiyath al-Din Abu'l-Fath Umar ibn Ibrahim Al-Nisaburi (1048–1122); Nishapur, Iran; astronomer and mathematician.

Umar ibn al-Khattab, ibn Nufayl ibn 'Abd al-'Uzza ibn Rayyah (c.581–644); companion of Prophet Mohammad (pbuh) and second caliph, ruling from Medina, Saudi Arabia (634–644).

Uthman ibn Affan, ibn Abi Al-'As ibn Umayyah (577–656); companion of Prophet Mohammad (pbuh) and third caliph (644–656).

Vitruvius, Marcus Pollio (c.70–c.25 BCE); Rome, Italy; architect and engineer.

Al-Walid ibn 'Abdulmalik ibn Marwan (668–715); Umayyad caliph who ruled from Damascus (705–715); he built the Umayyad Mosque in Damascus.

Sir Christopher Wren (1632–1723); London, UK; architect, astronomer and mathematician.

Sanad ibn Ali **al-Yahoudi** (9th century); Baghdad, Iraq; Jew converted into Islam, chief astronomer of al-Ma'mun, distinguished member of the House of Wisdom.

Yaqut, Ibn-'Abdullah Rumi al-Hamawi (1179–1229); Arab biographer, historian and geographer.

Al-Zahrawi, Abul Qasim Khalaf ibn al-Abbas, known in the West as Abulcasis (936–1013); Cordoba, Spain; physician and surgeon.

Al-Zarqali, Abu Ishaq Ibrahim ibn Yahya, also known as Arzachel (1028–1100); Toledo, Spain; astronomer who compiled the Toledan Tables.

Zheng He (1371–1433); Kunming, China; navigator and admiral.

Ziryab, Abul-Hasan Ali ibn Nafi' (789–857); Baghdad, Iraq; musician, astronomer, fashion designer and gastronome.

Aristotle and Alexander the Great from *Animals and their Uses* by Ibn Bakhtishu in the 13th century

Glossary

Abbasid dynasty A dynasty that ruled the Muslim caliphate from Iraq between 750 and 1258. The Abbasids are renowned for fostering learning and science. Their most distinguished caliphs are Harun al-Rashid (ruled 786-809) and his son al-Ma'mun (ruled 813-833), who made Baghdad the centre of science and learning. They founded the House of Wisdom, a famous library and scholarly centre in Baghdad. Harun al-Rashid is renowned in the West for gifting Emperor Charlemagne a water clock and an organ in 797 CE.

Aghlabids Muslim dynasty that ruled from 800-909, and were semi-independent of Baghdad. Their capital, al-Qayrawan, was a vibrant city during that time. Among their famous legacies is the water reservoir of al-Qayrawan. From al-Qayrawan they ruled Tunisia, Sicily and Malta.

Allah 'Allah' is the Arabic word for God, the supreme and only God, the Creator, who according to the Quran is the same God of the Bible.

Allahu Akbar *Allahu Akbar* is Arabic for 'God is the greatest.' The phrase is said during each stage of both obligatory and voluntary prayers. The Muslim call to prayer, or *adhan*, and call to commence the prayer, or *iqama* also contain the phrase. The actual title of this phrase is *takir*. In the Islamic world, instead of applause, often someone will shout '*takbir*' and the crowd will respond '*Allahu Akbar*' in chorus to show agreement and satisfaction.

Almohad One of the greatest medieval dynasties, who ruled North Africa (and much of Spain) from circa 1147 until the rise to power of the Merenids around 1269. The Almohad dynasty (from the Arabic al-Muwahhidun, i.e. 'the monotheists' or 'the Unitarians,' the name being corrupted through the Spanish), were a Berber Muslim religious power who founded the fifth Moorish dynasty in the 12[th] century, uniting North Africa as far as Egypt, together with Muslim Spain.

Al-Andalus The Arabic name given to the Iberian Peninsula when it was ruled by Muslims from 711 to 1492. Al-Andalus once encompassed the area extending from the Mediterranean to northern Spain, bordering the Kingdom of Aragon in the north. Today, Andalusia is used to denote the southern region of Spain. Different meanings have been suggested for al-Andalus, the most famous ones being the 'gardens' (in Arabic) and the land of the Vandals, rulers who inherited the Roman empire and ruled Spain before the Muslims.

Arab and/or Muslim The term 'Arab' is applied to those people who are of Arab origin, regardless whether they are/were Muslims or non-Muslims. 'Muslim' is used to refer to the people who adhere to the Muslim religion, which includes Arabs and non-Arabs, such as those people from Iran, Pakistan or Indonesia for example.

Asabiyah This is an Arabic word which can mean 'solidarity' or 'group consciousness' but is usually translated as 'group feeling.' At the most basic level, *asabiyah* is something that a person feels for his family, a kind of 'brotherhood.' According to Ibn Khaldun, the successful ruler is he who manages to spread and maintain the *asabiyah* to all members of the society, so that all think of one another as they would think of their own brothers.

Ayyubids A dynasty founded by the Muslim Kurdish general Salah al-Din al-Ayyubi

(d.1193), known to Christians as Saladin. Salah al Din established the Ayyubid dynasty in 1169. The Ayyubids united Egypt and Syria and other parts of the Muslim East, which enabled them to defeat the crusaders at Hattin and recover Jerusalem

Al Azhar A university connected to a mosque in Cairo named in honour of Fatima Az Zahraa, the daughter of Prophet Mohammad, from whom the Fatimid Dynasty claimed descent. The mosque was built in two years from 971 and the school of theology connected with it was founded in 988, which remains to this day. It is one of the oldest operating universities in the world.

Baidaq Pawn, in chess.

Al Barrani Al Barrani consists of a large dome covered hall in a bath house, incorporating a drum (below the dome) with stained glass windows. The Damascenes spent much of their talent on lavishly staining the walls of al Barrani with elegant tiles of dazzling colours, reflecting mirrors, and calligraphy plates welcoming clients and citing Arabic proverbs. It is here where they got ready to proceed to other sections of the *hammam* and where they retired after bathing.

Al-Baydah A village near Qaim in Iraq

Caliph Literally means 'one who replaces someone who left or died.' In Islamic context, this means a successor to the Prophet Mohammad (pbuh) as a political, military and administrative leader of the Muslims, but does not include a prophetic role

Caliphate The Islamic state or government, whose head is the caliph.

CE The Common Era, also known as the Christian Era.

Chatrang *Chatrang* is Persian for chess, and the oldest form of the game

Dinars Basic currency unit, consisting of 1,000 *Fils*.

Eid A Muslim, celebratory festival, of which there are two, one after fasting in the month of Ramadan (called *Eid al Fitr*), and the other in celebration after *Hajj* (called *Eid al Adhha*)

Faqih An expert in Islamic law.

Faras Arabic term for mare or horse, and the knight in chess.

Fatimid A dynasty, named after Fatima al Zahra, the daughter of Prophet Mohammad (pbuh), which rose to political domination in North Africa in 909. They are the founders of Cairo, the capital city of Egypt, in 969.

al-Fihrist Literally this means 'a table of contents' or 'an index.' *Al Fihrist* is an index of all books written in Arabic by Arabs or non Arabs. It was written by Abu al-Faraj Muhammad ibn Ishaq ibn Muhammad ibn Ishaq, also called ibn al-Nadim. He began to make this catalogue of authors and the names of their compositions for use in his father's bookstore. As he grew older, he became interested in the many subjects he read about in books, or which he learned about from friends and chance acquaintances. So, instead of being merely the catalogue for a book shop, *al Fihrist* became an encyclopaedia of medieval Islamic culture

Fiqh Literally meaning 'knowledge and understanding,' it is the understanding and applications of *sharia* (divine law) from its sources.

Al Fustat Al Fustat is the first capital of Islamic Egypt established in 642 by 'Amru ibn Al- 'As, and was probably named after the Roman military term *fossatum*, or encampment.

Hadith Narrations of the sayings of the Prophet Mohammad (pbuh), which form one of the major sources of Islamic law. Each *hadith* is composed of a basic text the

authenticity of which was guaranteed by a chain of witnesses and narrators.

Hajj Pilgrimage to Mecca in Saudi Arabia.

Hammam Arabic public bath.

Haram Sacred, holy and/or prohibited.

Ifriqiya In medieval history, *Ifriqiya* or *Ifriqiyah* was the area comprising the coastal regions of what are today western Libya, Tunisia, and eastern Algeria. In modern Arabic, the term simply means 'Africa.'

Imam One who leads the prayers.

Jabal al-'arus A mountain in Cordoba, Spain.

Ka'bah Literally, 'a high place of respect and regard.' It is the sacred building in the centre of the al-Haram al-Shareef Mosque at Mecca, Saudi Arabia. It is the centre towards which Muslims around the world pray. It accommodates the divine black stone.

Kiswa Literally 'a cover.' The holy Ka'bah is covered with new *kiswa* (textile cover) every year on the tenth *Dhul Hijjah*, which coincides with *Hajj*. Every year, the old *kiswa* is removed, cut into small pieces and gifted to certain individuals, visiting foreign Muslim dignitaries and organizations.

Koshk Turkish for kiosk.

Kutubiyyin The word '*kutubiyyin*' is a Moroccan (Arabic) name for bookmakers.

Madrasa The word *madrasa* means a 'school,' and evolved originally from the lectures organized in mosques before schools became an independent entities. These days *madrasa* has a different meaning, and thousands of *madrasas* around the world are said to be educational institutions, usually teaching Islamic sciences or law.

Maghreb The Arabic world was traditionally divided into two parts, the Mashriq or eastern part and the Maghreb or western part (literally, 'the west' or 'where the sun sets'). Geographically it is defined as the region of the continent of Africa north of the Sahara desert and west of the Nile - specifically, the modern countries of Morocco, Western Sahara (annexed and occupied by Morocco) Algeria, Tunisia, Libya and to a much lesser extent Mauritania.

Mamluk Originally Turkish slaves that formed part of the Abbasid army. The Mamluks were a member of the Turkish speaking cavalry that went on to rule Egypt and Syria under the 13th century Mamluk dynasty.

Manarah Arabic for minarets of the mosque. Literally means 'lighthouse.'

Mihrab A niche in the wall of the mosque that indicates the direction in which one should pray, towards Mecca.

Minaret A tower from which the muezzin or crier, calls people to prayer.

Minbar A pulpit for the Imam, or prayer leader.

Miswak A cleaning stick, actually a twig from certain trees, essentially the arak tree botanically known as Salvadore persica, used for cleaning the teeth.

Mithqals Weights.

Mosque A public place for worship and prayer for the Muslims.

Mu'allim Islamic teacher.

Muhandis Engineer or architect.

Al-Muhtasib Al-Muhtasib is literally 'a judge' (*qadi*) who takes decisions on the spot, in any place and at any time, as long as he protects the interests of the public. His responsibilities are almost endless in order

to implement the foregoing principle: commanding the good and forbidding the evil of wrongdoing. *Al Muhtasib* and/or his deputies, like a full judge, must have high qualifications of being wise, mature, pious, well poised, sane, free, just, empathic, and a learned scholar or *faqih*. He has the ability to ascertain right from wrong, and the capability to distinguish the permissible, *halal*, from the non permissible, *haram*. So, al Muhtasib is entrusted to secure the common welfare and to eliminate injuries to society as a whole, even if such honourable tasks require him to take a stance against the ruling governance. In short, he must be an appointee (fully authorized), pious and just.

Muwaqqit Timekeeper, a wise man given the task to observe and decide on the times of prayers.

Pbuh Peace (and blessings of Allah) be upon him (Prophet Mohammad); a vow of devotion and belief that Mohammad was the Prophet of God (Allah). This phrase is repeated by Muslims every time they pronounce or hear the name of Prophet Mohammad.

Qadi A Muslim judge.

Al Qahwa Arabic term for coffee.

Al-Qayrawan It is a town in North East Tunisia and a sacred city of Islam. Founded in 670 by Uqbah bin Nafi, an Arab leader, it was the seat of Arab governors in West Africa until 800. Under the Aghlabid dynasty (800–909), it became the chief centre of commerce and learning, and remained so during the Fatimid rule (909–921). The city was ruined (1057) by Bedouin invaders, the Banu Hilal tribe, and subsequently was supplanted by Tunis.

Al Qali This word was derived from *qalai* (to dry or roast in a pan). *Al qali* is 'the substance that has been roasted' or 'ashes of the plant saltwork.' In Europe, both substances were named natron.

Qamara A dark room, also a ship's cabin.

Qanat It is a type of underground irrigation canal between an aquifer on a piedmont zone to a garden on an arid plain. The word is Arabic, but the system is best known from Iran.

Qibla An Arabic word referring to the direction of Mecca, Saudi Arabia, that Muslims should face toward when they pray.

Rajab The seventh month in the Islamic lunar calendar.

Ramadan It is the ninth month in the Islamic calendar, best known as the holy month of fasting for Muslims.

Rawdiya The inhabitants of the early Islamic world were enchanted by greenery. This love of plants is clearly shown in a genre of poetry, the *rawdiya* or garden poem, probably of Persian origin, which came to be one of the main poetic forms in the Abbasid orient from the 8th to the 10th centuries.

Rihla Literally means 'journey, travel and travelogue'. It is a piece of writing about travel.

Safavid dynasties The Safavids, an Iranian dynasty that ruled from 1501 to 1736. They had their origins in a long established Sufi order which had flourished in Azerbaijan since the early 14th century. Its founder was Sheikh Safi al Din (1252–1334), after whom it is named.

Al Saratan Arabic term for cancer.

Seljuks A Turkish dynasty that ruled across Persia, Anatolia and Turkey between 1038 and 1327. They are best renowned for their great promotion of learning, arts and trade. The Seljuks gave the *madrasa* (school) its final shape and definition, as it became a completely separate building from the mosque. They were also behind the rise of the so-called caravanserais, a hostel complexes providing

free accommodation, food and services for trading caravans. In the arts, they are best remembered for the introduction of the *iwan* plan and *muqarnas* vaulting.

Shadoof Machine for lifting water, consisting typically of a long, pivoted wooden pole acting as a lever, with a weight at one end. The other end is positioned over a well. The *shadoof* was in use in ancient Egypt, and is still used in Arab countries today.

Sheikh A social title of respect given to an elderly, wise or a religious person in the community.

Sharia *Sharia* is the law system inspired by the Quran and the sayings of Prophet Mohammad (pbuh). Sharia is often referred to as Islamic law.

Souk The market place.

Sufism Mystical belief and practice in which the truth of divine love and knowledge of God is sought.

Al-Tasrif Literally means 'conducting' or 'handling a certain issue.' Here it is a medical encyclopaedia written by Abul Qasim Khalaf ibn al-Abbas al-Zahrawi, also known as Abulcasis. The complete title is *Al-Tasrif li-man 'ajiza 'an al-taalif*, or *The Method of Medicine*, translated as *The Arrangement of Medicine*. It had 1500 pages, showing that Abulcasis was not only a medical scholar, but a great practising physician and surgeon. It influenced the progress of medicine in Europe. See the section on 'European Medicine' to learn more about it.

Tawaf The circumambulation or walking clockwise around the Ka'bah in Mecca.

Thikr The action of remembering God (Allah), consisting of the repetition of words in praise of God.

Al-Ud The *'ud* (also spelt oud) is a musical instrument common to the Arab culture. It's a stringed instrument slightly smaller than a guitar, with eleven strings in six courses. Some *'uds* may have more or fewer strings; common are versions with thirteen strings in seven courses, or ten strings in five courses.

Ulama Scholars of the Islamic sciences.

Vizier/wazir Chief minister of the Abbasid caliphs and also government official in Islamic states.

Waqf Religious charitable institutions that manage various gifted and donated financial assets. The *waqfs* finance mosques, *madrasas*, fountains, and other public services. Their role has been greatly undermined by modern state intervention.

Waraq Paper.

Warraq Paper manufacturer and/or writer.

Wudhu Performance of the ritual of ablution. Before offering the prayer, one must be in good shape and pure condition. It is necessary to wash the parts of the body which are generally exposed to dirt or dust or smog, like the hands, mouth, nose, face, arms, hair, ears and feet. This is called ablution, and the person who has performed it is ready to start his prayer.

Persian manuscript showing
Timur enthroned at Balkh

Image Credits

The publishers would like to express their thanks to the museums, archives, and photographers for kindly agreeing to allow the reproduction of their works.

Illustrations are identified by page numbers. The following abbreviations have been used: a.=above, b.=below, m.=middle, l.=left, r.=right

© Aga Khan Award for Architecture, Professor Dogan Kuban: 198[b.r.]

© Aga Khan Visual Archive, M.I.T.: (Kara Hill, 1989) 96[m.], 157; (Jamal Abed, 1987) 159[r.]; (M. al-Asad, 1986) 201[m.], 206[l.]; (Hatice Yazar, 1990) 288[l., a.]

© Ali Hasan Amro/MuslimHeritage.com: Cover [background], 29, 49, 71, 107, 163, 250, 274[b.], 311, 316-321

© Anna Pietrzak, Nicholaus Copernicus Museum, Frombork: 284[a.], 323[a.r.]

© Art and Architecture: 215[a.]

© Artur Ekert: 47[r.]

© Beinecke Rare Book and Manuscript Library, Yale University: 307[a.l.]

© Bibliothèque nationale de France, Paris: 59, 63[a.], 100, 125[l.], 128[r.], 130[b.r.], 134[l.], 257[a.], 258, 270[l.]

© Bildarchiv Preussischer Kulturbesitz/Art Resource, NY: 162[a.]

© Bodleian Library: (MS Pococke 263) 89[l.]; (MS Pococke 375 folios 3v-4r) 236, 251[a.]

© Bridgeman Art Library: (Biblioteca Universitaria, Bologna) 156[b.]; (Bibliotheque de la Faculte de Medecine, Paris) 168 [b.]; (Musee Atger, Montpellier) 98; (Topkapi Palace Museum, Istanbul, Turkey) 229[b.l.]; (British Library, London, UK/British Library Board. All Rights Reserved.) (Or 2784 fol.96) 355; (British Library, London, UK/British Library Board. All Rights Reserved.) (Or 2838 f.20v) 361

© By permission of the British Library: (T 12646) 21[a.]; (Add.25724 f.36) 73; (3754-05) 132[l.]; (Add.Or 1699) 136[r.]; (16325) 303[b.]

© Castilla-La Mancha University (Spain): 95

© Chris Juliano: 97

© Chris Barton: 113

© Corbis: 114[b.r.]; (Chris Hellier) 52[r.], 226[b.]; (Bettmann) 56; (Arthur Thevenart) 111[l.]; (Roger Wood) 112 [r.]; (M. ou Me. Desjeux) 120[b.l.]; (Paul A. Souders) 132[r.]; (Kazuyoshi Nomachi) 133[l.]; (Summerfield Press) 135 [r.]; (Paul Almasy) 122, 202[a., m.].

© Crown Publishers Inc., a division of Random House Inc. 1977: 191

© Culver Pictures inc.: 323[b.].

© David Alcock www.thecravenimage.co.uk: 201[b.], 202[r.]

© Dean & Chapter: 210[r.]

© Den Islamske Informasjonforeningen, Oslo, Norway: (Karima Solberg) 88[r.]

© Department of Printing and Graphic Arts, Houghton Library, Harvard College Library: (Typ 620.47 452 F) 92[b.]

© Dr James T Goodrich: 189

© Durham Cathedral: 199[a.r.]

© Eddie Gerald: 203[a.r.]

© Edinburgh University Library: 108.

© Enigma Museum, http://w1tp.com/enigma: 268[b.r.]

© Eric Tischer: 142[r.]

© Erich Lessing: 196[r.], 290[b.]

© Estate of Dr Ahmed Moustafa, Research Centre for Arab Art and Design: 301

© Forschungsbibliothek Gotha: 144[r.].

© Garnet Publishing: 249[b.]

© Gothard Astrophysical Observatory: 304

© Guildhall Library, London: 12[r.]

© Hikmet Barutcugil of Ebristan, Istanbul, Turkey: 137

© History of Science Collections, University of Oklahoma Libraries: 28[b.], 173[b.].

© Hussein Gouda www.egypthome.net: 145[b.r.]

© Ibn Battuta Mall: 261[a.].

© Izzet Keribar/Images&Stories: 215[b.], 220.

© Jan Adkins: 265[a.].

© John Rouette: 203[b.r.].

© Jonathan C. Horton MD PhD: 176.

© José A. Entrenas, Infocordoba.com: 205[a.l.].

© José Vicente Resino: 194[r.].

© JP Lescourret: 205[a.r.].

© Library of Congress, Prints and Photographs Division: 47[l.], 52[a.l., b.l.], 79[b.], 88[b.l.], 90, 169[l.], 179[b.], 238[b.l.], 253[a.], 313.

© Mamure Öz of Topkapı Palace Museum Studio (Gilding) and Huseyin Oksuz (Calligraphy) 84[r.].

© Mark Blackburn: 150[a.].

© Mary Evans Picture Library: 74[a.l.], 195.

© Mashreq Maghreb: 214[b.]

© Courtesy of Mike Rock: 18[m.]

© Millet Library, Istanbul: 152, 164[b.], 167

© Mukhtar and Soraya Sanders; Inspiral Design, Istanbul: Cover [3rd and 5th from left], 20[r.], 23[a.r.], 37[a., b.], 44, 58[a.], 76[b.], 80[b.], 82[b.], 84[l.], 141[a.], 200[a.], 207[a., b.], 216[a.], 273[r.], 300[a.].

© MuslimHeritage.com: 16, 17, 20[b.l.], 23[b.l.], 162[b.]; (Ahmed Salem) 55[r.]; (Aidan Roberts) 14[r.], 116, 117, 118[l.], 119; (Rabah Saoud) 205[b.r.]; (Samia A Khan) 209[b.]; (Wai Yin Chung) 81[b.l.].

© National Library Board Singapore: 264, 266[r.].

© National Library of Medicine: 172[b.].

© National Maritime Museum, London: 241, 295

© National Museums Liverpool (Liverpool Museum): 81[r.].

© National Portrait Gallery, London: 40[b.l.], 212[b.l.].

© Oman Ministry of Natural Heritage and Culture: 190.

© Paul Preacher: 66[r.]

© Peter Sanders: 222

© Phillip Collier: 142[b.l.]

© Photo Scala, Florence, 1990: 199[a.l.]

© Princess Wijdan Fawaz Al-Hashemi: 147[a.l., a.m., r.].

© Princeton University Press: 277[b.].

© Ralph Aeschliman: 305.

© Renata Holod: 198[b.l.].

© Richard B Levine: 182

© Richard Seaman: 199[b.].

© Courtesy of the Royal Asiatic Society, London, 18[b.r.]

© The Royal Library, Copenhagen: 187

© Saudi Aramco World/PADIA. (Nik Wheeler) 51, (Norman MacDonald) 126[b.l.], 129[l.], 149, 260, 261, (Michael Winn) 248[b.]; (S M Amin) 252[b.]; (Khalil Abou El Nasr) 257[b.]; (Robert Azzi) 294[b.], 297, 125[r.].

© Sayed Al Hashimi/MuslimHeritage.com. 14[r.], 17[l.], 116[l.], 117, 118[r.], 119, 201[r.], 170, 234, 235, 238[b.r.], 246[m.], 265[b.], 266[b.l.]

© Science Museum/Science & Society Picture Library 130[b.m.], 136[b.l.], 175, 185[b.].

© Simon Keynes: 151[a.l.].

© Courtesy of Suleymaniye Library, Istanbul: 19[l.], 83, 181, 183[b.r.], 272[b.m.], 298[b.], 307[b., m., a.r.].

© The Golden Web Foundation: 128[l.]

© The Trustees of The British Museum: 144[l.], 147[b.l.], 150[b.], 292

© The Trustees of the Chester Beatty Library, Dublin: 13.

© Tips Images: 34[b.l.]

© Courtesy of Topkapı Palace Library, Istanbul. 31[r.], 34[r.], 36, 39, 53, 115, 116[r.], 159[l.], 180[b.r.], 183[a., b.l.], 197, 223, 224[r.], 225, 227[r.], 254, 255, 270[m., r.], 271[r.].

© Turkish Postal Authority: 179[a.].

© University Library, Istanbul: 192, 194[b.l.], 280, 285, 289, 293, 299

© University of St Andrews Library: 161

© V&A Images/Victoria and Albert Museum: 31[l.], 139[l.], 141[b.], 143, 229[a.]

© Courtesy of Walter B. Denny: 127[l., r.], 314 (Topkapı Palace Library).

© Werner Forman Archive/Metropolitan Museum, New York: 184 [b.r.].

© www.worldreligions.co.uk: 61, 114[b.l.].

Thanks and Acknowledgements

THIS BOOK IS PUBLISHED by FSTC as part of the 1001 Inventions series of products. Complementing this are a travelling exhibition, teachers' educational pack, posters and website (www.1001inventions.com)

This book would not have come to fruition without the dedication and perseverance of all staff working at FSTC and external consultants, including Muslim Heritage Consulting. No royalty fees are being received by any party

SPONSORS

Special thanks for financial support to: International Holdings Group (UAE), The El Sayed Foundation, The Home Office Cohesion & Faiths Unit (UK), The University of Manchester (UK), The Wellcome Trust (UK), North West Development Agency (UK), Office of Science and Technology DTI (UK), Museum of Science and Industry in Manchester (UK), Nik Nak Clothing Ltd (UK), El Rahmah Trust(UK), The Muslim Youth Foundation (UK), and the Bin Hamouda Group (UAE). Thanks are also due to the British Association for the Advancement of Science (UK) for their continued encouragement and endorsement and to the Foreign and Commonwealth Office (UK) for their assistance in promoting the project and their financial contribution towards the 1001inventions.com website

SUPPORTERS

Extended appreciation for assistance and support to: The renowned historian Professor Ekmeleddin Ihsanoglu, Secretary General of the Organisation of Islamic Conference; the members of the Muslim Heritage Awareness Group and in particular to Peter Raymond, Vice President of the Parliamentary and Scientific Affairs committee; Professor Charles Burnett, Warburg Institute; Professor Emilie Savage-Smith, Oriental Institute Oxford; Dr Anne-Maria Brennan, London South Bank University, Dr Ruth Barnes, Ashmolean Museum Oxford, Professor Mohammed El Gomati, York University, Professor Aziz Sheikh, Edinburgh University; Dr Emily Winterburn, National Maritime Museum, Paul Keeler, CEO Golden Web, Cambridge, Howard Firth, Orkney International Festival, Dr Saleema Kauser, Manchester Business School; Yasmin Khan, Science Museum, London; Dr Zohor Idrisi, Senior Researcher London; Dr Mahbub Gani, Kings College London, Dr Subhi Al-Azzawi, Architect, Kent, Dr Okasha El-Daly, Petrie Museum UCL; Dr Rim Turkmani, Imperial College London, Lee Bryant, Headshift Ltd, Farikh Mirza, London; Bettany Hughes, London; Marianne Cutler, The Association for Science Education, Hatfield; Professor John Pickstone, Centre for the History of Science, Technology and Medicine, University of Manchester; Peter Fell, University of Manchester; Tim Fulton, IHG, Dubai, and Samar El Sayed, Managing Director of the El Sayed Foundation. Last but not least, much appreciation goes to Professor Stephen Parker, Head of School LLC, University of Manchester for his continued support and encouragement.

Special thanks and gratitude to Yaqub Yousuf, CEO International Holdings Group (UAE), for championing the development of this book and supporting the teams that worked to publish it.


بفرخ ترین ساعت آمد بتخت
خدیو جهانگیر فیروز بخت

1001 Inventions

Muslim Heritage in Our World

Second Edition

WHAT DO COFFEE BEANS, torpedoes, surgical scalpels, arches and observatories all have in common? Were Leonardo Da Vinci's flight ideas originals? Who devised the casing for pill capsules and where did Fibonacci learn to flex his mathematical fingers?

All these answers can be found here in *1001 Inventions: Muslim Heritage in Our World*, written in an accessible style for those with limited knowledge of either Islam or history. A golden age of civilization, from 600 and 1600 CE, will unfold, because medieval Muslims were trailblazers in fields as diverse as medicine and mechanics, cartography and chemistry, education and engineering, architecture and astronomy. No area was too obscure to miss the scrutiny of enquiry backed up by rigid scientific experimentation.

So get comfortable with this guidebook and prepare to begin on a voyage of discovery through a thousand years of science and technology into the lives of medieval pioneers whose ingenious inventions have helped create our world today.

www.1001inventions.com
www.MuslimHeritage.com

PUBLISHED BY FSTC LTD
ISBN-13: 978-0-9552426-1-8
£29.50 in the UK / $59.50 in the USA

'This glorious book overflows with the great ideas of the Muslim middle ages. From al-Jazari and his elegant clocks and al-Kindi and Ibn al-Haitham with their revolutionary optical thtes, experiments, and books, to the astronomers who navigated across the desert by the stars, and the map-makers who put north at the bottom, every page is a mine of joyous information. There are even recipes to try out, and everything is beautifully illustrated. I wish I had had this book fifty years ago.'

Adam Hart-Davis; Photographer, Writer and TV Science Presenter of BBC Series *What the Ancients Did for Us*

ISBN 978-0-9552426-1-8

9 780955 242618 >